Comprehensive Long-Term Environmental Action Navy (CLEAN)

NAVAL STATION TREASURE ISLAND
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

SURFACE CONFIRMATION RADIATION SURVEY

DRAFT REPORT

Department of the Navy
Western Division
Naval Facilities Engineering Command
San Bruno, California 94066-0727

CLEAN

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Surface Confirmation Radiation Survey (SCRS) was undertaken to evaluate sources of possible radioactive contamination in several areas within Naval Station Treasure Island, Hunters Point Annex (HPA). Potential sources of radiation included radium-coated dials and also mixed fission products present as fallout that may have been present on the surfaces of ships sent to HPA for repair and maintenance. Fallout particles could have been mixed with sandblast wastes generated during repainting operations. Radium-contaminated materials were identified in several IR sites at HPA during the SCRS, but no mixed fission products were detected at any site in concentrations above normally expected background levels.

Prior to the start of the SCRS, a high-volume air sampling and analysis program for airborne gross alpha and beta emitting particulates (PRC, 1991) was conducted, as described in Section 1.1 of the SCRS Report. The investigation evaluated the concentrations of long-lived radioactive airborne alpha and beta emitting particulates during non-intrusive activities, i.e., activities that did not disturb the soil. Background concentrations of gross alpha and beta emitting airborne particulates were encountered during the air sampling program.

During the SCRS, the HPA facility was systematically screened for surface radioactivity using a combination of surface gamma radiation surveys, soil sample analysis, soil radon flux measurements, groundwater analysis, downhole gamma radiation logging, and cursory radiation surveys of selected buildings and sites.

The results of the SCRS indicated (1) that no mixed fission products were detected; (2) radioisotopes other than ^{226}Ra were measured to be within expected background levels in soil samples collected and analyzed; and (3) ^{226}Ra-containing materials are present at the IR-01 and IR-02 landfills, and, to a minor extent, at IR-07 and PA-18.

Some ^{226}Ra-containing materials in the soil at the two landfill sites, exposed to the air or close to the surface, may present a potential alpha radiation exposure pathway to humans through direct bodily contact and subsequent inhalation or ingestion of radioactive dusts. Although inhalation of alpha-containing dusts may be possible, preliminary results of air sampling during trenching indicate that there is no increase in airborne alpha particulates during these intrusive, subsurface activities. In the future, trenching activities will include wetting of soils to minimize the generation of dust. Presently, the IR-01 and IR-02 sites are fenced off preventing access to the site by the general public. The ^{226}Ra-containing materials in the landfill areas are also gamma radiation emitters; however, due to low gamma activity, these materials do not present an increased health hazard to

on-site workers. The largest number of identified, individual, surface point source radiation anomalies are within IR-02 in an area approximately 600 feet by 600 feet.

The IR-03, IR-15, and PA-19 sites did not exhibit anomalous gamma activity during the surface walkover gamma survey, and do not warrant further investigation.

Laboratory analysis has shown that at 13 of the 137 surface soil sampling locations, ^{226}Ra continued to be detected in the soil after the visible point sources were removed. This suggests either that ^{226}Ra is relatively immobile and generally has not migrated from its initial disposal location or the source materials have disintegrated. At the locations where ^{226}Ra was identified in the soil, it is possible that radium has leached into the soil, or is in a finely crushed state not distinguishable from the soil.

Radon gas flux rate measurements from the soil were used as an adjunct to the surface gamma survey to assess the potential for buried ^{226}Ra in the landfill areas. Radon gas is a radioactive decomposition product of ^{226}Ra and can be released into the atmosphere from soil that contains ^{226}Ra. Radon gas flux rate measurements revealed that radon releases from the soil were elevated only over known, identified gamma anomalies. These gamma anomalies were relatively small and their contribution to the atmospheric radon gas concentration at the sites was found to be negligible. Thus, after radon flux rate measurements were evaluated, other than in the localized anomalous areas already identified from the surface gamma radiation survey, buried ^{226}Ra wastes were not indicated. Air permeability of soils, a factor possibly influencing radon flux rates, will be evaluated under Phase II.

Groundwater was analyzed to determine if radioactive contamination exists in the groundwater beneath areas that contain radioactive anomalies. The EPA 900.0 analytical method used has a limitation in its application to sea water, i.e., water containing high concentrations of dissolved solids. Analysis of water for gross alpha activity using this method provided inconclusive results. The laboratory results suggest that beta activity in the groundwater may be due to potassium-40, a natural radioisotope present in sea water.

Downhole gamma radiation logging in nine wells was performed to evaluate if gamma activity associated with buried ^{226}Ra could be detected. The results of the gamma logging was inconclusive and did not provide additional information about the location of buried ^{226}Ra.

Cursory surface radiation contamination surveys of buildings and sites revealed two locations, Building 351A and an area within IR-14, that have alpha and gamma contamination above the

current maximum Navy unrestricted release criteria. Building 701 (ruins), Building 816 (former cyclotron site), and Dry Dock 4 showed no increase above normal background radiation levels.

As requested by the Navy, discrete, gamma emitting point source anomalies in the upper 6 inches of the landfill surface, that were identified during the SCRS, will be removed and disposed offsite through the Department of Defense (DOD) Low Level Radioactive Waste (LLRW) disposal program.

Additional investigations are recommended in selected locations to fully characterize the areas where anomalous radioactivities were identified in the SCRS. To better define the extent and distribution of ^{226}Ra-containing material at HPA the following seven tasks are recommended as part of the Phase II Radiation Investigation. (1) Trench and collect soil samples to characterize contamination below the surface, and performing air permeability testing of soils to assist in the evaluation of radon flux rate values. (2) Search archived Naval records to determine which buildings are former Naval Radiological Defense Laboratory (NRDL) locations and if they were previously released by the Navy for unrestricted use, and investigating identified NRDL buildings including the Building 351A sump area for structural and soil radiation anomalies. (3) Screen existing soil cuttings presently stored in drums for gamma activity. (4) Field screen archived soil samples previously collected from sites where radiation anomalies have been confirmed. These soil samples currently stored in Buildings 414 and 810 will provide information about gamma activity due to ^{226}Ra and other gamma emitters. (5) Perform downhole gamma logging in new soil borings, new well installations, and existing groundwater monitoring wells in OU-I and OU-IV to evaluate surrounding soil gamma activity. (6) Evaluate groundwater for ^{222}Rn and ^{226}Ra using radiochemical methods and identify alternative methods for gross alpha and beta analysis of water samples. (7) Move the safe that exhibits surface radioactive contamination from IR-14 to the radioactive materials storage area in Building 414 for disposal under the DOD LLRW disposal program.

The evaluation of alternative analytical methods for gross alpha and beta determination in groundwater is the first step in the evaluation of the potential for radioactive contamination in groundwater. High concentrations of dissolved solids seriously reduce the certainty of the results using the only accepted method currently available. Groundwater samples tested using the current EPA-approved gross alpha and beta analysis will likely continue to provide unreliable results. An alternate method is required that is unaffected by dissolved solids. Until a suitable screening method is identified, isotope-specific, radiochemical analysis for ^{226}Ra should be used.

In accordance with the health and safety plans prepared for all sites, worker exposure to radioactivity was monitored using thermoluminescent dosimetry (TLD) and urine bioassays.

Analytical results of TLD monitoring for external gamma radiation indicated that gamma exposure to workers was 0.00 rem and was in compliance with 10 CFR Part 20 Subpart D - Radiation Dose Limits for Individual Members of the Public that states 1) the dose in any unrestricted area from external sources does not exceed 0.002 rem in any one hour and 2) the total effective dose does not exceed 0.1 rem in a year. The urine bioassays for internal ^{226}Ra uptake indicated no exposures to on-site personnel.

A detailed work plan describing recommended Phase II Radiation Investigation tasks has been prepared and will be submitted shortly for agency review.

1.0 INTRODUCTION

PRC Environmental Management, Inc., (PRC) received Contract Task Order (CTO) No. 0155 from the Department of the Navy, Western Division (WESTDIV), Naval Facilities Engineering Command, under Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62474-88-D-5086. This CTO required PRC to perform a Surface Confirmation Radiation Survey (SCRS) to assess radiation contamination from radium (^{226}Ra)-containing materials along with other radionuclides that are associated with nuclear weapons testing at Naval Station Treasure Island, Hunters Point Annex (HPA) in San Francisco, California. The location of HPA in relation to the San Francisco Bay region is shown on Figure 1.

The scope of this investigation covers the identification of new areas of potential radioactive contamination, and confirms and specifies the locations of previously identified areas that may exhibit elevated radioactivity in soil and in underlying groundwater. A thorough survey was conducted of land areas that were suspected to contain radioactive materials using gamma-sensitive radiation detection equipment. The survey provided information about the relative surface distribution of discrete sources of radioactivity, as well as information about possible radioactive contamination in buildings suspected of storing, experimenting with, or handling radioactive materials.

^{226}Ra is of primary concern at HPA and was specifically investigated since this radioactive material was used in instrument dials and other equipment that were disposed of on-site when HPA was an operational base. ^{226}Ra and its daughter products are alpha, beta, and gamma emitters. There are two landfill locations at the sites, IR-01 and IR-02, that may have received these wastes.

Soil samples were collected at locations where radioactivity was elevated. The samples were analyzed and used to identify the radioactive isotopes present in the landfill. To further characterize the extent of surface and sub-surface ^{226}Ra contamination, radon (^{222}Rn) collection canisters were placed at surrounding locations with elevated gamma activity. Radon gas, a decomposition product of ^{226}Ra, is evolved into the soil from the radioactive decay of ^{226}Ra. The amount of radon gas evolved may roughly represent the quantity of ^{226}Ra buried below the ground surface.

Groundwater samples were also collected in these wells for gross alpha and beta analysis and for analysis by gamma spectroscopy, which was used to identify specific gamma emitting isotopes. To assist in the determination of both vertical and horizontal distribution of buried ^{226}Ra, downhole gamma logging was used to measure gamma activities below the surface. .

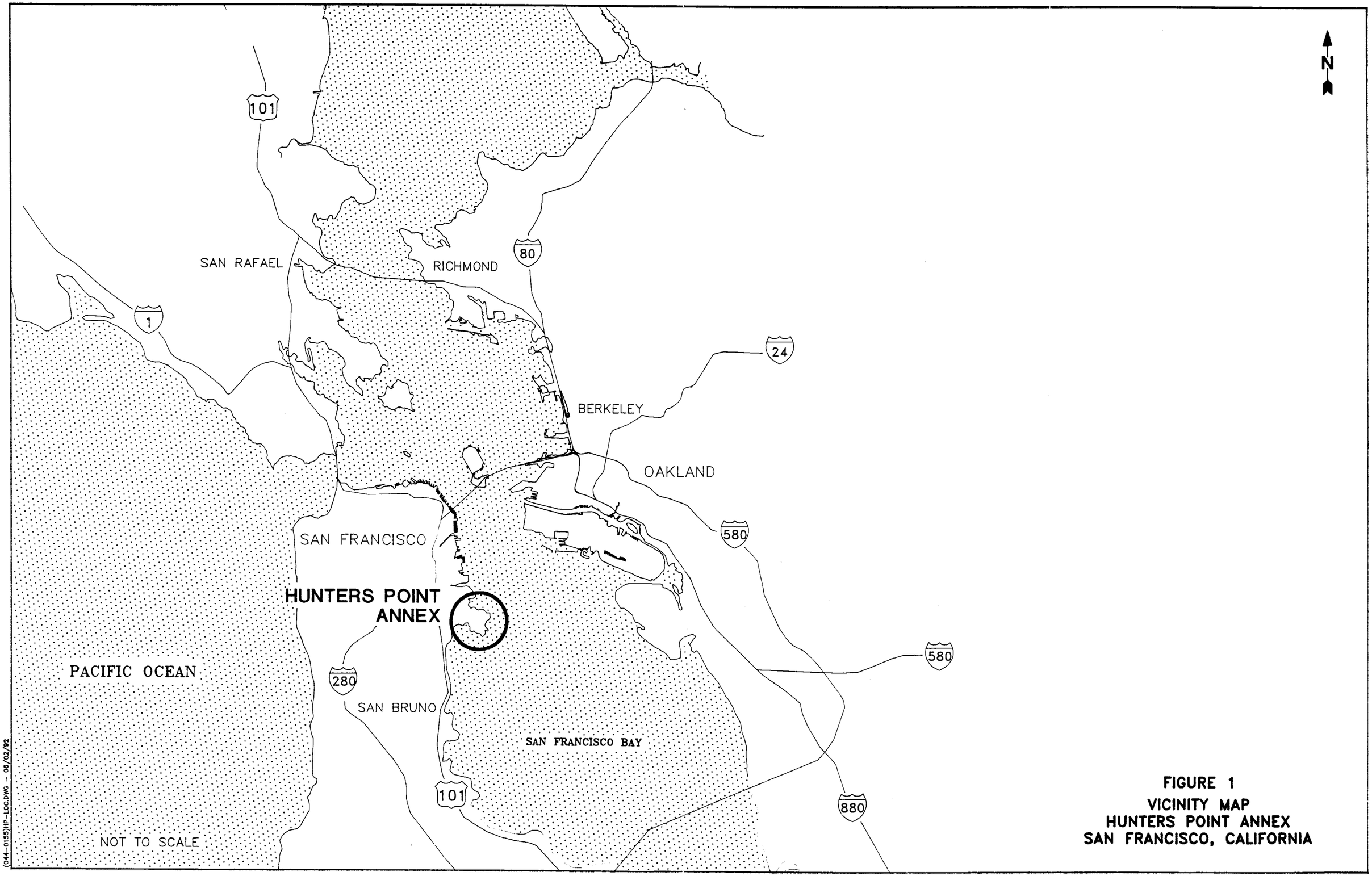

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FIGURE 1
VICINITY MAP
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

Additionally, radioisotopes associated with nuclear weapons testing (fission products) were also investigated in this survey. HPA was used as a repair facility for some of the ships that were involved in the testing of nuclear weaponry in the Pacific Ocean. Unsubstantiated claims maintain that sandblast wastes from the maintenance of these ships were disposed of on-site and may have contained some of the fission products associated with radioactive fallout. It is unclear at what locations the sandblast materials may have been disposed.

Another potential source of radioactivity comes from the past operations of the Naval Radiological Defense Laboratory (NRDL) at HPA during its active ship maintenance years. The types of radiation work that NRDL performed have not been clearly established, but appears to have included cyclotron operation and animal radiation studies. The buildings that were used by NRDL are largely in ruins, but several structures remain standing. Only 3 of 12 suspected radiation laboratory areas were investigated, since identification of many of the buildings as NRDL sites occurred late in this study. The remainder of these sites will require investigation at a later date and recommendations are provided in Section 7 of this report.

The major elements of this SCRS were performed by Thermo Analytical/Eberline (TMA), a subcontractor to PRC.

1.1 BACKGROUND

A preliminary surface radiation survey was performed at HPA by Harding Lawson Associates (HLA) in 1988 to establish if elevated radioactivity was present at the site (HLA, 1990). The Industrial Landfill (IR-01), Bay Fill Area (IR-02), Former Oil Reclamation Ponds (IR-03), and the Sub Base Area (IR-07) were surveyed for the purpose of screening these areas for gross gamma radioactivity. HLA established background gamma radioactivity for the site in 1988, by selecting 14 locations at HPA where sandblast waste and radioactive waste were not reported to have been disposed of. The average background gamma count rate plus 3 standard deviations of the established mean count rate was approximately 10,500 counts per minute (CPM), using a 1-inch by 1-inch sodium iodide (NaI) gamma scintillation detector.

Activity above 10,500 CPM was considered anomalous and significant. The results of the survey showed that the only area at HPA with significant elevated radioactivity was an area exhibiting gamma activity within IR-02 that exceeded twice the background count established for the area.

In the 1988 investigation, the study focused on elevated radioactivity at HPA in selected areas and whether radiation exposure posed a hazard to remedial investigation workers on the site. Sampling of soils was not performed and the vertical extent of radioactive contaminants in the IR-01 and IR-02 areas was not determined. The general area in which gamma anomalies were identified was mapped. Since permanent markers had not been placed at the anomalous locations, later field identification of the anomalous locations was difficult.

Prior to the SCRS, trenching activities were performed in 1991 to identify the edges of the landfills at the IR-01 and IR-02 sites. During these trenching activities, buried slag-like materials exhibiting alpha and gamma activity were discovered. The Navy contacted the Department of Energy (DOE) at Lawrence Livermore Laboratory, which sent radiological specialists to HPA to evaluate the radiation emitters found at the site. Through field gamma spectroscopic analysis, DOE determined that the source of activity appeared to be ^{226}Ra. The initial identification of ^{226}Ra as the source of radioactivity was subsequently confirmed by PRC through laboratory analysis that showed the source to have approximately 10,000 picoCuries per gram (pCi/g) ^{226}Ra, which is an alpha and gamma radiation emitter.

Also in 1991, following the discovery of sub-surface ^{226}Ra during trenching, an air sampling study was performed in which the concentrations of long-lived alpha and beta emitters in the air at IR-01 and IR-02, and in adjacent areas were measured (PRC, 1991). The study was conducted to determine whether there was an alpha or beta radiation particulate inhalation hazard due to resuspension of alpha- and beta-emitting radionuclides in dusts from ^{226}Ra sources on or near the surface at IR-01 and IR-02.

The data produced by the SCRS found that the average long-lived beta airborne particulate concentrations were higher off-site than on-site. However, the difference between the off-site control locations and on-site concentrations were not significant at the 95 percent level of confidence. All of the measured airborne concentrations of long-lived alpha and beta emitter activities were less than $1x10^{-14}$ microCuries per cubic centimeter of air ($\mu Ci/cc$). Both the off-site and on-site air concentrations were found to be similar to those found in typical background locations throughout the United States. No long-lived alpha and beta airborne radioactive particulate inhalation hazard was evident from the study.

Long-lived, rather than short-lived radioactive particulates, were evaluated in the study by holding the air filters for approximately 7 days after collection before analyzing them, which allowed any unsupported ^{222}Rn and daughter products to decay. This procedure, typical for this type of sampling, was necessary because the concentrations of ^{222}Rn, a ^{226}Ra radioactive decay chain

daughter (see Figure 2 which schematically depicts the ^{226}Ra decay chain), and ^{220}Rn (naturally occurring thorium-232 daughter) in ambient air are always high enough to interfere with the gross alpha count measurement of long-lived isotopes. The immediate analysis of an air filter without allowing an appropriate holding time would result in a marked increase in apparent gross alpha and beta activity from short-lived radium and thorium daughters. These daughters would not have been produced from the long-lived isotopes collected on the filter during sampling and would elevate the result. The elevated count would seriously bias the survey and an erroneously high concentration of alpha and beta activity in the air would be reported.

To prevent public access to contaminants at IR-01, IR-02, IR-03, IR-05, IR-14, and IR-15, the Navy completed the installation of fencing around these areas in December 1991.

1.2 PURPOSE

The objective of the SCRS was to (1) confirm the previously reported anomalies and to better define the areal extent and location of gamma-emitting anomalies within IR-01, IR-02, IR-03, IR-07, IR-14, IR-15, PA-18, and PA-19; and (2) make recommendations, if required, for a more comprehensive investigative study to evaluate the quantity and types of contamination at HPA caused by radioactive materials.

1.3 REPORT ORGANIZATION

The remainder of this report presents the results of the SCRS performed at HPA.

- Section 2.0, Technical Approach, describes the methodology used in performing this survey.
- Section 3.0, Site Description, briefly discusses the location and physical characteristics of the HPA site.
- Section 4.0, Field Activities, describes the specific operations conducted on-site.
- Section 5.0, Results, provides details of the results of the surface walkover gamma survey, analysis of soil and groundwater samples collected, radon flux (activated carbon) canister measurements performed on a site-specific basis, downhole gamma radiation logging, and cursory surveys of specific buildings and sites suspected of radioactive contamination.
- Section 6, Quality Assurance/Quality Control (QA/QC), presents the results of the QA/QC procedures used for this study.
- Section 7.0, Recommendations, presents a list of recommendations for consideration for future implementation as part of the characterization activities at HPA.
- Section 8.0, References, lists the reference documents used during the SCRS.

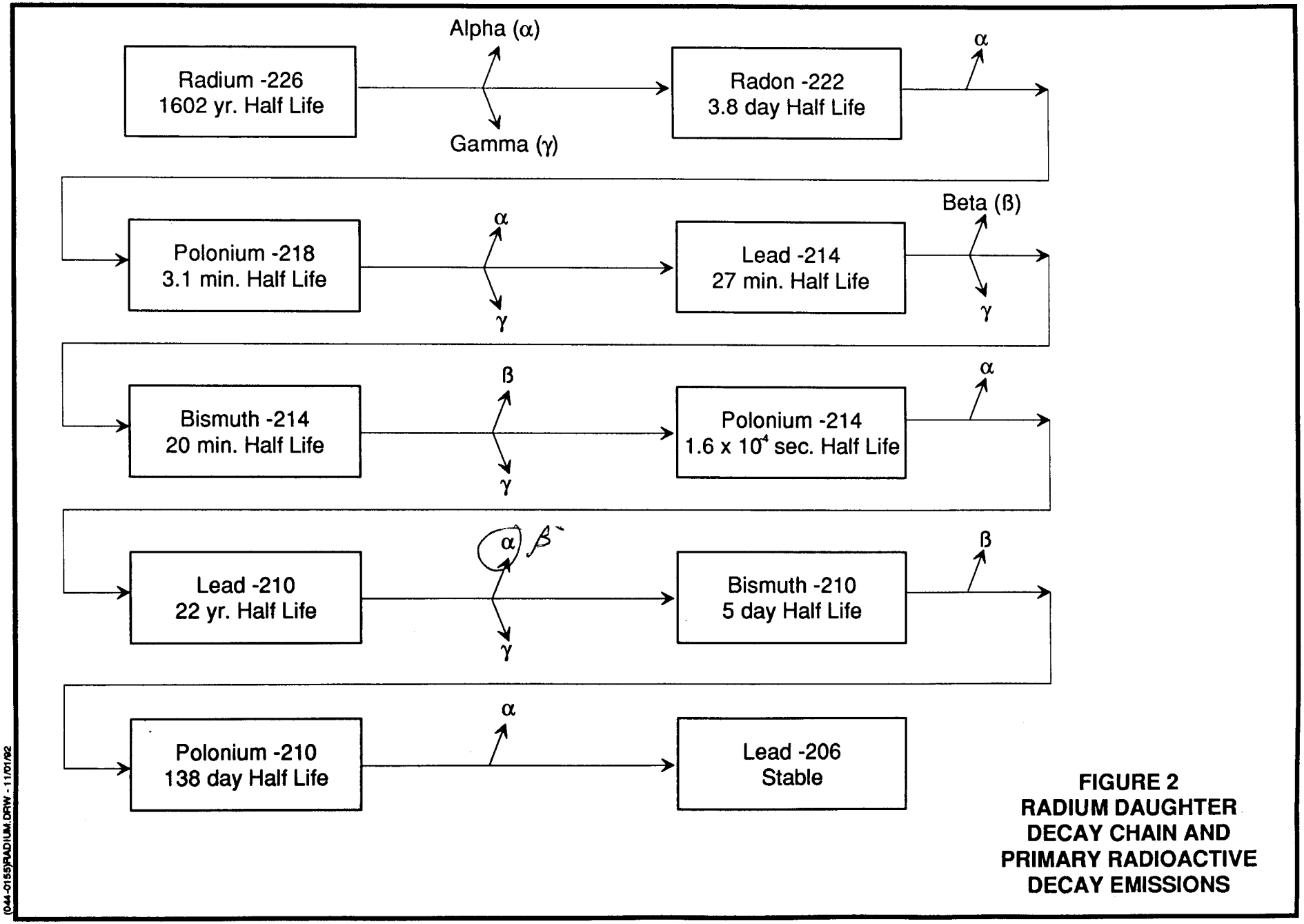

FIGURE 2
RADIUM DAUGHTER DECAY CHAIN AND PRIMARY RADIOACTIVE DECAY EMISSIONS

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- Appendix A contains the field sample collection forms used during the SCRS.
- Appendix B shows the surface gamma survey data collected for background locations, downhole locations, ground surfaces, and cursory surveys.
- Appendix C contains laboratory data.
- Appendix D contains the field operating procedures used during the SCRS.
- Appendix E shows the field equipment list, response check information, and control charts used with all field equipment.

2.0 TECHNICAL APPROACH

The selection of specific IR and PA sites for the SCRS was based upon the rationale presented below. Many of the sites, IR-01, IR-02, IR-03, IR-07, and PA-18, have historically received wastes generated from shipbuilding and repair activities. Although IR-01 was not identified as containing gamma-emitting anomalies by HLA in the previous radiation survey performed in 1988 (HLA, 1990), unconfirmed estimates speculate that up to 6,000 pounds of ^{226}Ra-containing wastes may have been disposed of in IR-01 (EMCON, 1987).

The 1988 survey performed at IR-01 was accomplished by taking gamma radiation measurements at and between 200-foot grid node points over the entire IR-01 area. This method of radiation detection served well for the establishment of general background activities over a large area, but did not provide enough precision to efficiently locate buried, randomly-dispersed, low-activity diffuse or point sources. ^{226}Ra-coated dials are an example of point sources. Sandblast wastes containing finely divided radioactive materials is an example of a diffuse source. Recent 1990 groundwater data indicate that alpha radiation emitters may exist within the groundwater underlying IR-01 (HLA, 1991). Therefore, IR-01 was included in this survey.

IR-02 was previously surveyed for gamma radiation and found to contain gamma emitting anomalies within a 420-foot by 240-foot area (HLA, 1990). The location of these anomalies was not well identified and required more accurate location and activity data. Groundwater data also suggested that alpha radiation emitters may also exist within the groundwater underlying IR-02 (HLA, 1991). Therefore, IR-02 was included in this survey. IR-03 is situated within the boundaries of IR-02, and was included in the survey because of its proximity to potential radioactive sources.

IR-07 was also surveyed previously for gamma radiation in 1988 and was found to have gamma scintillation counts below the background established for the site. However, IR-07 was reported to have been used as a disposal area for potentially radioactive sandblast wastes (EMCON, 1987). Sandblast wastes generated during hull maintenance of ships exposed to above-ground

nuclear weapons testing in the Pacific Ocean during and after World War II may have contained various amounts of nuclear fission products associated with radioactive fallout from nuclear tests.

As discussed previously, the radiation detection methods used at IR-07 during the 1988 survey were not sufficiently discerning to efficiently locate buried, randomly-located, diffuse sources of radioactive contamination. Consequently, the presence of diffuse radioactive contamination associated with sandblast waste could not be ruled out; therefore, IR-07 was included in this survey.

IR-14 and IR-15 were included in this survey because a NRDL site formerly located at Building 506, and its associated annex buildings, may have used a stainless steel underground storage tank (UST) for radioactive liquid waste. The primary concern at this site was leakage and contamination from the suspected UST.

PA-18 was included in this survey because it is continuous with IR-07 and no obvious boundary exists between the two sites. Fill materials used in IR-07 may underlie PA-18.

PA-19 reportedly has sandblast residues placed in two roadway planters south of and adjacent to Building 901. The residues could possibly contain fission products adhered to the paint on ships serviced at HPA.

A land survey covering IR-01, IR-02, IR-03, IR-07, IR-14, IR-15, and PA-18 was performed by a subcontracted firm. Semi-permanent monuments at grid nodes on 300-foot centers were installed. PA-19 was not included in the land survey due to its very small area and distance from the main survey areas, but it was surveyed on a localized grid layout. Following the installation of monuments at the grid nodes, the grid was subdivided by PRC on 60-foot centers and marked by steel spikes. TMA/Eberline, before performing the SCRS, further subdivided the grid on 30-foot centers.

Areas within any 30-foot subgrid that exceeded the general area gamma activity range by 50 percent had a pin flag placed at that location to identify it for further investigation that would include soil sampling or radon flux canister placement.

Throughout the SCRS, locations showing anomalous gamma activities were identified in the field with pin flag markers and then plotted on a site map. During the survey, biased and systematic soil samples, and water samples were collected for laboratory radiological analysis. Biased soil samples were collected at surface locations that exhibited anomalous gamma activities as previously

defined by the SCRS. Systematic soil samples were collected randomly at 30-foot grid nodes using a rate of approximately one sample per 2 acres. Downhole gamma logging was performed inside well casings for those wells where groundwater was collected for radiological analysis. Radon flux canisters were placed around surface locations that were determined to have anomalous gamma activity for that location, to evaluate the ^{222}Rn gas released into the soil from the decay of ^{226}Ra.

3.0 SITE DESCRIPTION

HPA is located in southeastern San Francisco at the tip of a peninsula extending into San Francisco Bay, as shown on Figure 3. The Navy property encompasses 965 acres, which consists of 443 acres in the San Francisco Bay and 522 acres on land, 70 to 80 percent of which is level lowland area. The central northwest portion is occupied by a moderately sloping, southwest-trending ridge.

The northern and eastern shores are equipped with dry dock and berthing facilities. The Navy used the facilities from 1930 through 1975. The Triple A Machine Shop operated at HPA as a commercial ship repair facility from 1975 to 1987. Currently, the site is being used by private businesses for limited commercial and industrial activities and minimally by the Navy for custodial maintenance and other official uses.

3.1 GEOLOGY

The bedrock beneath HPA is primarily serpentinite of the Franciscan Complex, a tectonic assemblage of highly metamorphosed, igneous, and sedimentary deposits. Within the San Francisco Bay estuary and over much of the HPA, the Franciscan Complex is overlain by undifferentiated sedimentary deposits consisting of consolidated sands and clays, which are in turn overlain by estuarine deposits of clay, silt, sand, and peat, termed "Older Bay Mud."

While "Older Bay Mud" deposits may be present in the offshore areas of HPA, insufficient test boring data are available to differentiate the "Older Bay Mud" from the underlying, undifferentiated sedimentary deposits. Consequently, all of the stiff soils logged beneath the younger bay mud are collectively grouped with the undifferentiated sedimentary deposits.

Development of HPA has involved placement of fill material over both bedrock and Bay mud. Within the shipyard, fill is estimated to cover 70 to 80 percent of the area, with bedrock left exposed in the central upland area. This fill material consists of two general types. The first type of fill material is derived predominantly from excavation of bedrock varying in composition from serpentinite and associated ultramafic rocks to Franciscan sandstone, chert, greenstone, and shale.

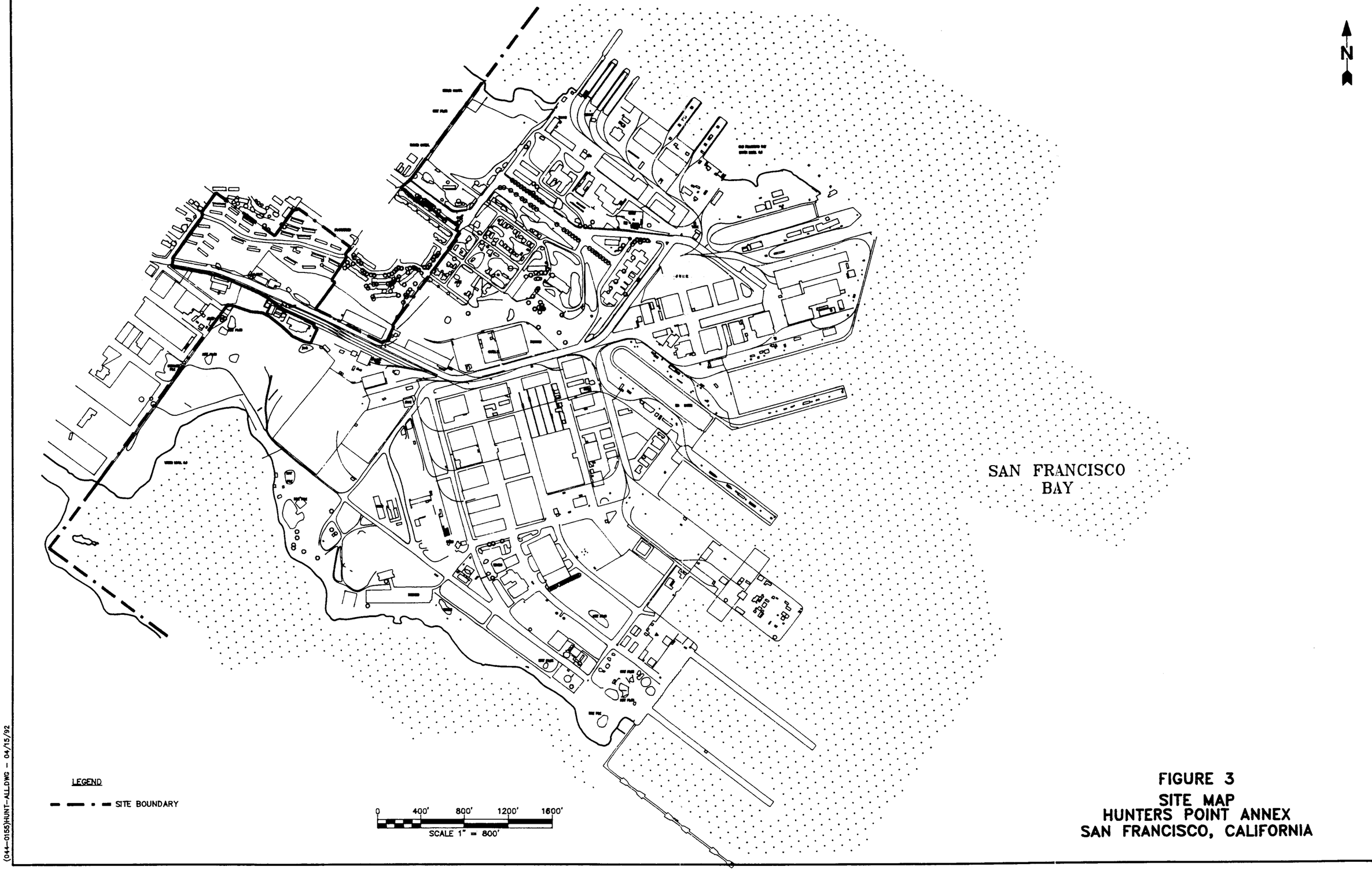

FIGURE 3
SITE MAP
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

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The second type of fill material is mainly sandblast grit placed along the Bay margin and used as a means of disposal for these materials.

3.2 HYDROGEOLOGY

Little information is currently available regarding the local hydrogeology at HPA. Some information has been collected during past investigations. Groundwater occurs sporadically within the unconsolidated fill and alluvial materials and also occurs within the fractured bedrock underlying the site. The depth to water in the unconsolidated material ranges seasonally from 2 to 12 feet in one boring (near Building 813) at the base of the prominent ridge area at Hunters Point.

In general, groundwater beneath the site probably flows radially from inland areas of higher elevation toward the Bay. However, local groundwater flow directions may be quite complex because of variations in topography and the hydraulic properties of subsurface fill materials. In some areas, local flow directions may also vary periodically because of the influence of tidal fluctuations in the Bay and localized recharge from storm events.

4.0 FIELD ACTIVITIES

This section describes the field activities that were performed to collect data concerning the extent, amount, and types of radioisotopes present at HPA.

4.1 SURVEY GRID PLACEMENT

As previously described, a 300-foot by 300-foot grid was surveyed by a subcontracted firm over IR-01, IR-02, IR-03, IR-07, IR-14, IR-15, and PA-18. At each 300-foot grid node, a semi-permanent monument consisting of a 6-foot steel fence post and a spike were driven into the ground. Approximately 76 monuments were installed. The grid was oriented along true north and correlated to the California Coordinate System as shown on Figure 4. Grid points were placed as far into the intertidal zone as practical.

To better delineate the anomalous locations following the installation of the grid node monuments, the grid was subdivided by PRC on 60-foot centers. Twelve-inch steel spikes, marked with surveyor's tape, were driven at 60-foot intervals creating 25 points per 300-foot grid sector space. Before beginning the SCRS, the grid was further subdivided into 30-foot by 30-foot subgrids by TMA/Eberline. Yellow pin flag grid markers were placed at the 30-foot subdivision for the duration of the survey.

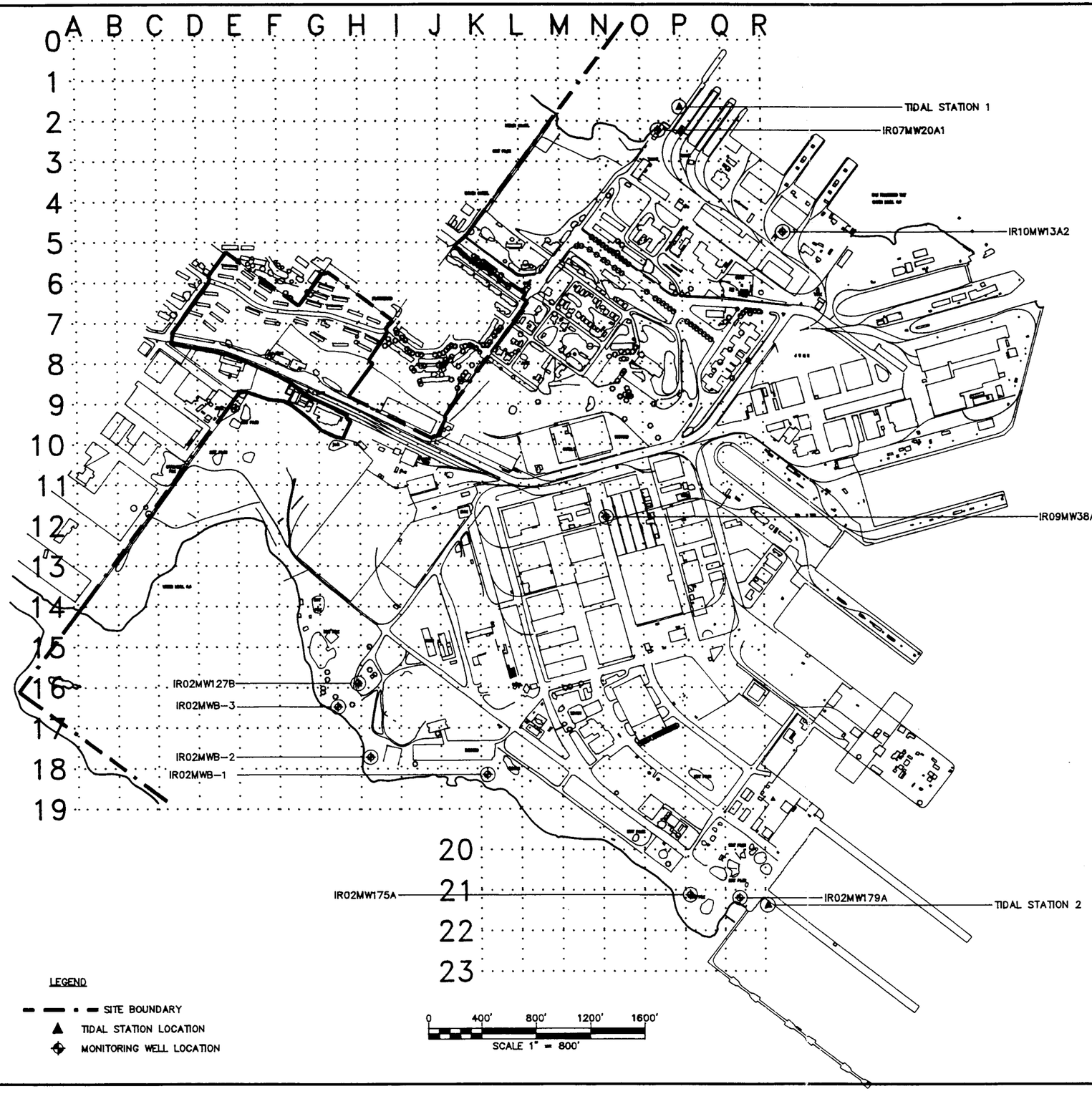

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FIGURE 4
GRID MAP AND LOCATIONS OF SAMPLED WELLS AND TIDAL STATIONS HUNTERS POINT ANNEX SAN FRANCISCO, CALIFORNIA

4.2 GRID COORDINATE SYSTEM

Each major 300-foot grid axis was given a label. East-west running axes (X axis) were labelled with the letters A through R. North-south running axes (Y axis) were labelled with the numerals 0 through 23. Each X and Y axis between 300-foot grid nodes was further subdivided into ten 30-foot divisions. These divisions were labelled 1 through 9 from west to east on the X axis and 1 through 9 from north to south on the Y axis.

Divisions between 30-foot nodes were measured in feet. For example, the grid coordinates H.03.24, 17.08.12 represent: X-coordinate H, plus three 30-foot grid blocks east plus 24 more feet east, intersected by, Y-coordinate 17, plus eight 30-foot grid blocks south plus 12 more feet south.

4.3 ESTABLISHMENT OF BACKGROUND VALUES

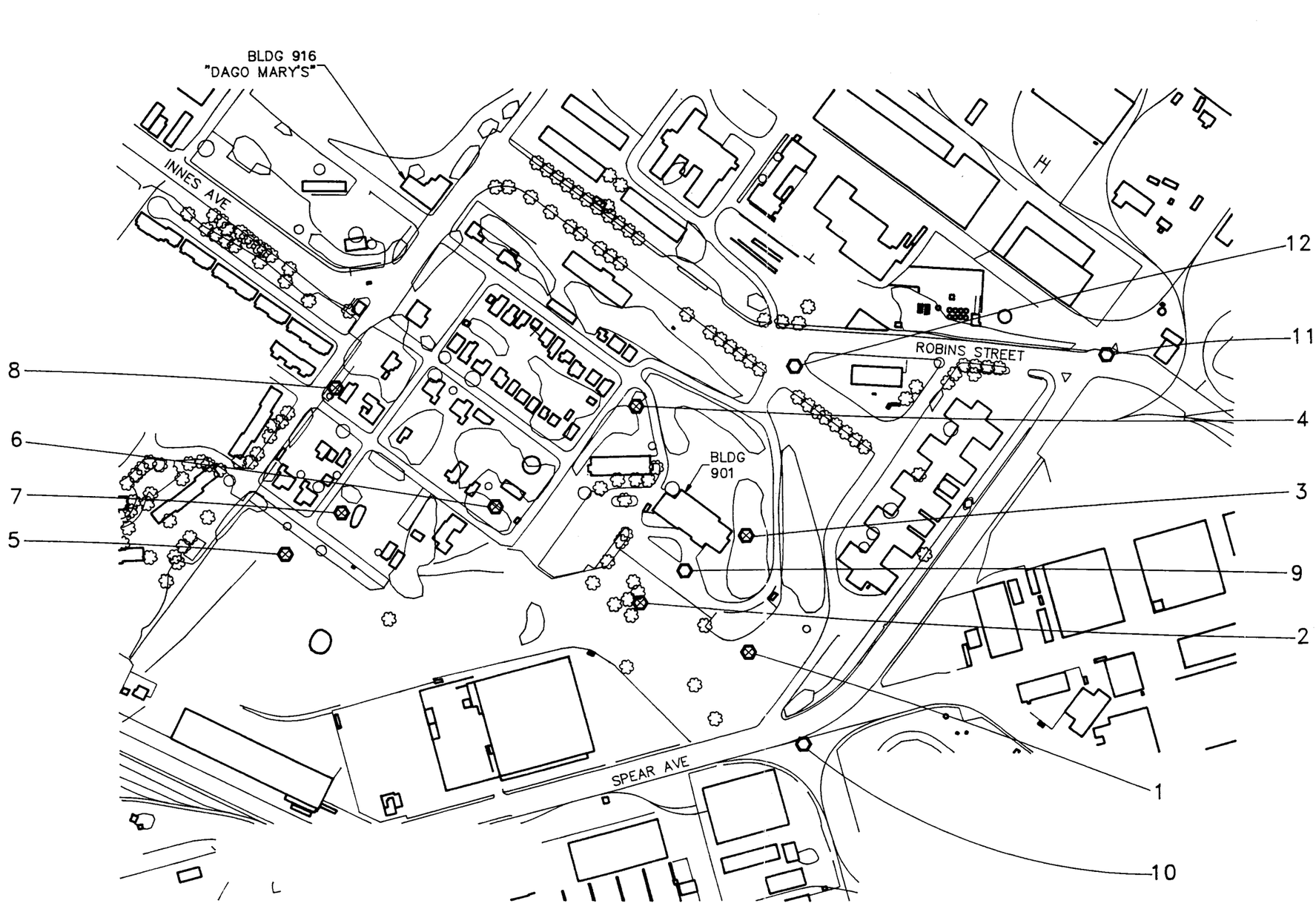
Prior to conducting the SCRS, a radiation survey was completed at 12 locations chosen at HPA to determine background radiation levels. Since some of the areas to be investigated were paved or compacted gravel roadways, four of the background locations were chosen over streets on the site, but away from any of the IR sites suspected of elevated gamma activity.

The locations were selected based upon geological units at the site that were believed to have influence upon background gamma levels. Eight surface soil samples were collected for laboratory analysis by gamma spectroscopy. Figure 5 shows a map of locations used to establish background gamma activity and for collecting background soil samples for the entire facility.

The background gamma count rate was determined at each location, at both the surface and 3 feet above the surface, with a 2-inch by 2-inch NaI gamma scintillation detector. All count rates were determined from a 5-minute integrated measurement and expressed in CPM.

The background gamma count rate for the scintillator was taken to be the unbiased average of the count rates measured at each background location. In addition, at each background location, the gamma exposure rate was measured using a Reuter-Stokes pressurized ionization chamber (PIC), with an integration period of approximately 7 to 8 minutes, sufficient to impart an exposure of 1.0 μR to the detector.

Although this formal method of background gamma count rate determination was used to establish the facility background gamma activity values, it was found to be inappropriate for use during the actual surface walkover gamma survey or as a benchmark value for the determination of



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LEGEND

- BACKGROUND LOCATION
- BACKGROUND LOCATION AND SOIL SAMPLE (LOCATIONS 1–8)

0 150' 300' 450' 600'

SCALE 1" = 300'

FIGURE 5
LOCATIONS USED FOR ESTABLISHMENT OF BACKGROUND GAMMA ACTIVITY AND COLLECTION OF BACKGROUND SOIL SAMPLES
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

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anomalous gamma activity. After the survey began, the actual gamma background activity at the landfill sites was found to be significantly lower than the formally established value. This problem was overcome by using general area gamma activity established at each 30-foot by 30-foot grid location as the benchmark gamma activity value for anomaly determination. This solution was considered valid since the landfill consisted of many types of soils that may have been imported onto HPA. There is little reliable information about the origin of much of the surface landfill soils. If this alternate method of background determination had not been selected, many of the low activity anomalous areas, possibly indicative of buried radium containing materials, might not have been recognized as such. Since the surface gamma survey constituted the first of a series of measurements designed to identify areas with elevated gamma activity caused by buried radium, an estimate of background needed to be adjusted for local fluctuations due to variations in soil types. Karp (1988) indicates that gamma surveys should be used in conjunction with surface radon flux rate measurements to identify buried ^{226}Ra.

4.4 SURFACE WALKOVER GAMMA SURVEY

The surface walkover gamma survey was performed within the areas shown on Figure 6, which shows the SCRS sites. The intent of this surface walkover gamma survey was to provide accurate and reliable information of the areal extent, location, and activity levels of surface radioactive contamination at HPA. Areas with anomalous gamma activity were located in IR-02. This confirmed locations found during the 1988 survey that were identified as exhibiting anomalous gamma activity. When anomalous areas were identified in any 30-foot by 30-foot subgrid, pink pin flag markers were either placed in the soil over the anomaly or the anomalous location was marked with red paint.

The number of anomalies within each subgrid was recorded along with the range of gamma count rate activities in CPM. A count is the specific response of a detector and its ratemeter/scaler to an interaction with one photon or particle emitted from a radioisotope. The count rate is directly affected by the efficiency of a detector to a specific radioisotope energy. The count rate information and the coordinates of the anomalies were recorded on field survey forms for later transferral to a site map.

The walkover gamma survey portion of the SCRS was conducted using an Eberline ESP-1 or ESP-2 ratemeter coupled to a 2-inch by 2-inch NaI gamma scintillation detector. The walkover gamma survey was performed with the detector as close as practical to ground level to locate anomalous gamma areas within each 30-foot by 30-foot subgrid.

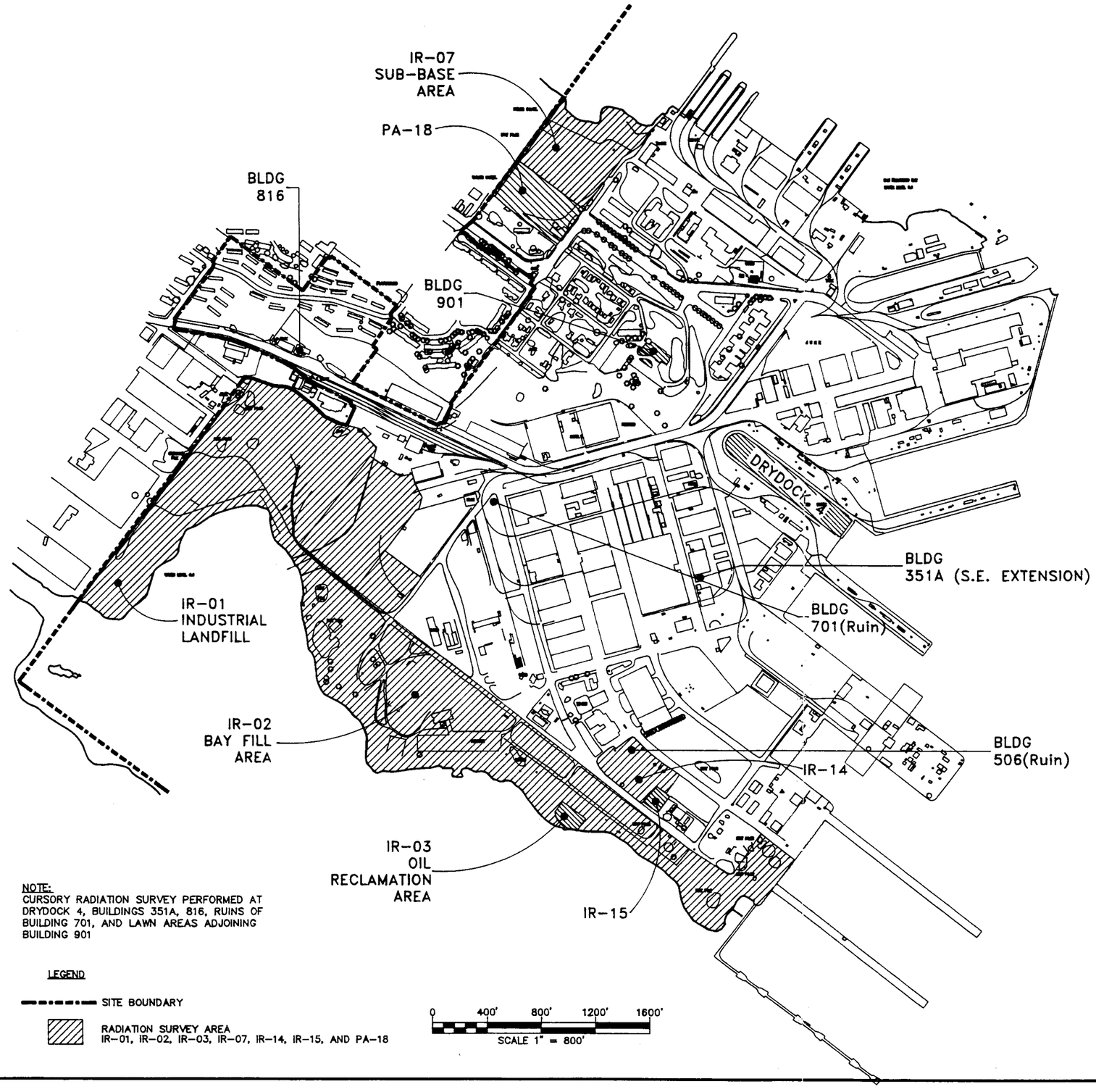

FIGURE 6
SURFACE CONFIRMATION RADIATION SURVEY SITES
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

Gamma emitting sources exhibiting activities typical of those anomalies found at HPA can be detected reliably at soil cover depths of less than 1 foot. The survey also included reasonably accessible Bay sediments associated with IR-01, IR-02, IR-03, and IR-07 at low tide, if the adjacent IR site exhibited anomalous gamma activity.

4.5 SOIL SAMPLE COLLECTION

Soil sampling was performed using two approaches. Biased soil samples were collected at locations that were identified as having an anomalous gamma count rate. Additionally, random, unbiased soil samples were collected to establish survey wide radionuclide activity averages.

Soil samples collected were analyzed using gamma spectroscopy to identify and quantify gamma emitters. The gamma emitting radioisotopes specifically analyzed for were ^{40}K, cesium-137 (^{137}Cs), ^{226}Ra, thorium-228 (^{228}Th), radium-228 (^{228}Ra), and americium-241 (^{241}Am). Other significant spectral peaks were also characterized. A representative sample of 10 percent of the total number of soil samples collected were analyzed for plutonium-238 (^{238}Pu) and plutonium-239/240 ($^{239/240}Pu$). Field sample collection forms with location and description of samples are provided in Appendix A.

Systematic and biased surface soil samples were collected based upon the criteria as described below:

- A series of 50 systematic soil samples were collected across HPA at the rate of one sample per 2 acres. These locations were established by random number generation within each 300-foot by 300-foot grid block. These samples were collected from the surface to a depth of approximately 6 inches.

- Forty-five biased soil samples were collected at selected locations that were identified in the SCRS as anomalous. These locations were in sands and slags, and at discrete source locations. Soil samples were collected with a stainless steel trowel by removing the soil overburden down to the point of the source emitter to a depth no greater than 18 inches. Following removal of the source, if one was present or visible, a soil sample was collected from the first 6 inches of material below the source location. In instances where a discrete source could not be identified or isolated, as with slag materials and some soils, the sample included the material with elevated gamma activity.

- If ^{226}Ra-containing source material or other visible gamma source was found, it was removed and placed in a 55-gallon drum located in radioactive materials storage in Building 414. Biased samples were collected also at selected locations, such as the large anomalous area surrounding grid coordinate H.00.00, 16.00.00, to account for the range of different materials that may be present at the site.

- Twenty-one boundary soil samples were collected from the surface to a depth of 6 inches in IR-02 around the large anomalous area surrounding grid coordinate H.00.00, 16.00.00. These samples were taken to establish a surface lateral boundary for that anomalous area.

- All of the collected soil samples were analyzed using gamma spectroscopy to identify gamma emitters. Additionally, 10 percent of the soil samples collected were submitted for ^{238}Pu and $^{239/240}Pu$ analysis using alpha spectroscopy.

All soil samples were collected with stainless steel sampling trowels that were decontaminated with a water spray bottle and surveyed for radioactivity prior to reuse. Rinse blanks were collected from the final water rinse of this equipment.

4.6 RADON FLUX CANISTER PLACEMENT

A total of 370 radon flux canisters, filled with activated charcoal, were placed on the ground surface at locations around selected anomalies and surrounding areas with elevated gamma activity at a distance of up to 6 feet from the anomaly to determine radon emission from the soil. Flux canisters were placed to detect radon, a radioactive gas emitted into the soil from the decay of ^{226}Ra. Increased radon concentrations emanating from the soil may indicate that ^{226}Ra sources are buried in the soil at that location. Radon flux rate information is used to assist in locating sources that are too far below the surface to be detected by gamma walkover survey.

Radon flux canisters were placed at selected locations at and around anomalous areas. As ^{226}Ra decays to ^{222}Rn, the radon gas is released from the soil. Radon adsorbs to the carbon in the canister and is captured. Approximately 24 hours after placement, the canisters were removed from the ground surface and sealed with PVC tape.

Gamma spectroscopic analysis of the radon daughters (predominantly ^{214}Bi) was performed within 7 days after collection. The laboratory equipment used was a 3-inch by 3-inch NaI detector coupled to a gamma spectrometer, designed to scan for gamma energies, in the range of 270-663 thousand electron volts (keV), typically associated with radon daughters.

The results were then expressed as a radon flux rate value of picoCuries per square meter per second ($pCi \cdot m^{-2} \cdot s^{-1}$), a normalized value used to compare relative soil radon emanation values from site to site. A correlation of CPM to $pCi \cdot m^{-2} \cdot s^{-1}$ could not be made to define a direct relationship between the two data.

The lack of a direct relationship may be attributed to the different matrices where source material was found during soil sampling activities. ^{226}Ra-containing materials, some being sealed

sources, may also somewhat restrict the release of gaseous radon into the soil, while the slag/soil contaminated materials may release radon into the soil at a faster rate.

Twenty-five of the radon flux canisters were placed over known anomalies surrounding the grid coordinate H.00.00, 16.00.00 for relative comparison purposes with canisters placed in non-anomalous areas. Another 25 of the radon flux canisters were placed at non-anomalous locations surrounding grid coordinate H.00.00, 16.00.00 to determine if additional ^{226}Ra sources might be located. The gamma count rate at ground surface was established for each radon flux canister location prior to canister placement.

Other radon flux canisters were placed at the rate of five per 30-foot subgrid in areas where the gamma activity exceeded background activity by 50 percent and in areas where gamma activity increased by 50 percent relative to adjacent subgrids. Additionally, 25 radon flux canisters were placed laterally 10 feet away from the 12 locations where the gamma background count rates were taken to establish background radon emission rates.

There were three primary large anomalies containing multiple gamma sources and several small anomalies at HPA that were investigated for radon flux rates. These locations included the large anomalies found surrounding grid coordinate H.00.00, 16.00.00 in IR-02, the slag-like material found in IR-01 around grid coordinate C.00.00, 13.00.00, and the several anomalies found around grid coordinate Q.00.00, 21.00.00 in IR-02.

4.6.1 IR-01

Radon flux canisters were placed at three anomalous areas where ^{226}Ra-containing materials or slag were identified. A total of 158 radon flux canisters were placed in 36 different subgrid locations. Figure 7 shows the radon flux canister placement locations at IR-01.

4.6.2 IR-02

In the large anomalous area at grid coordinate H.00.00, 16.00.00, 25 canisters were placed directly on anomalies, ranging in gamma activity from 24,000 CPM to 670,000 CPM. Twenty-five radon flux canisters were placed within the large anomalous area at locations with non-anomalous gamma activity. Forty-nine radon flux canisters were placed in 12 different subgrid locations. Figure 8 shows the radon flux canister placement locations at IR-02. Figure 9 shows the radon flux canister placement location surrounding grid coordinate H.00.00, 16.00.00 at IR-02.

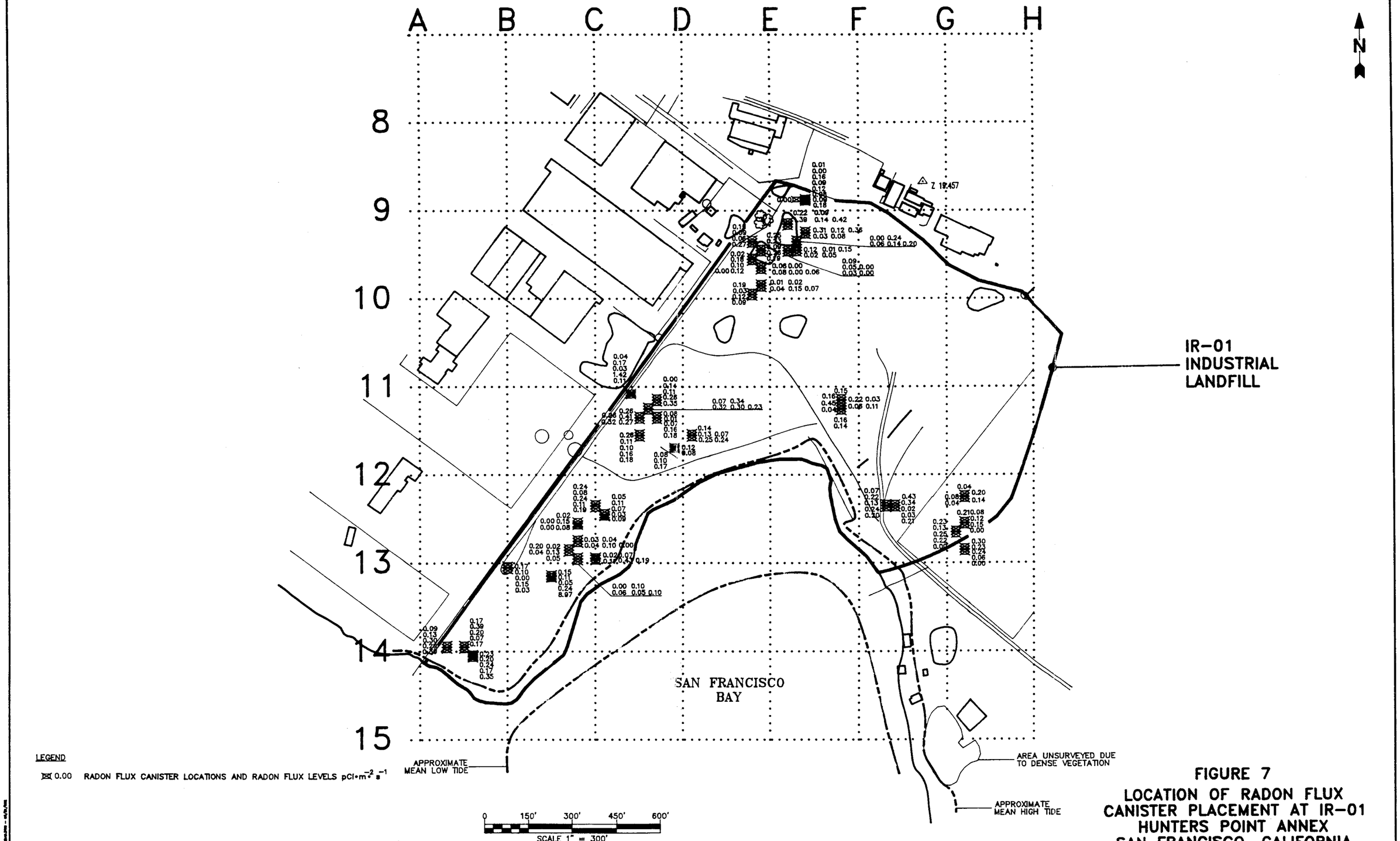

FIGURE 7
LOCATION OF RADON FLUX CANISTER PLACEMENT AT IR–01
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

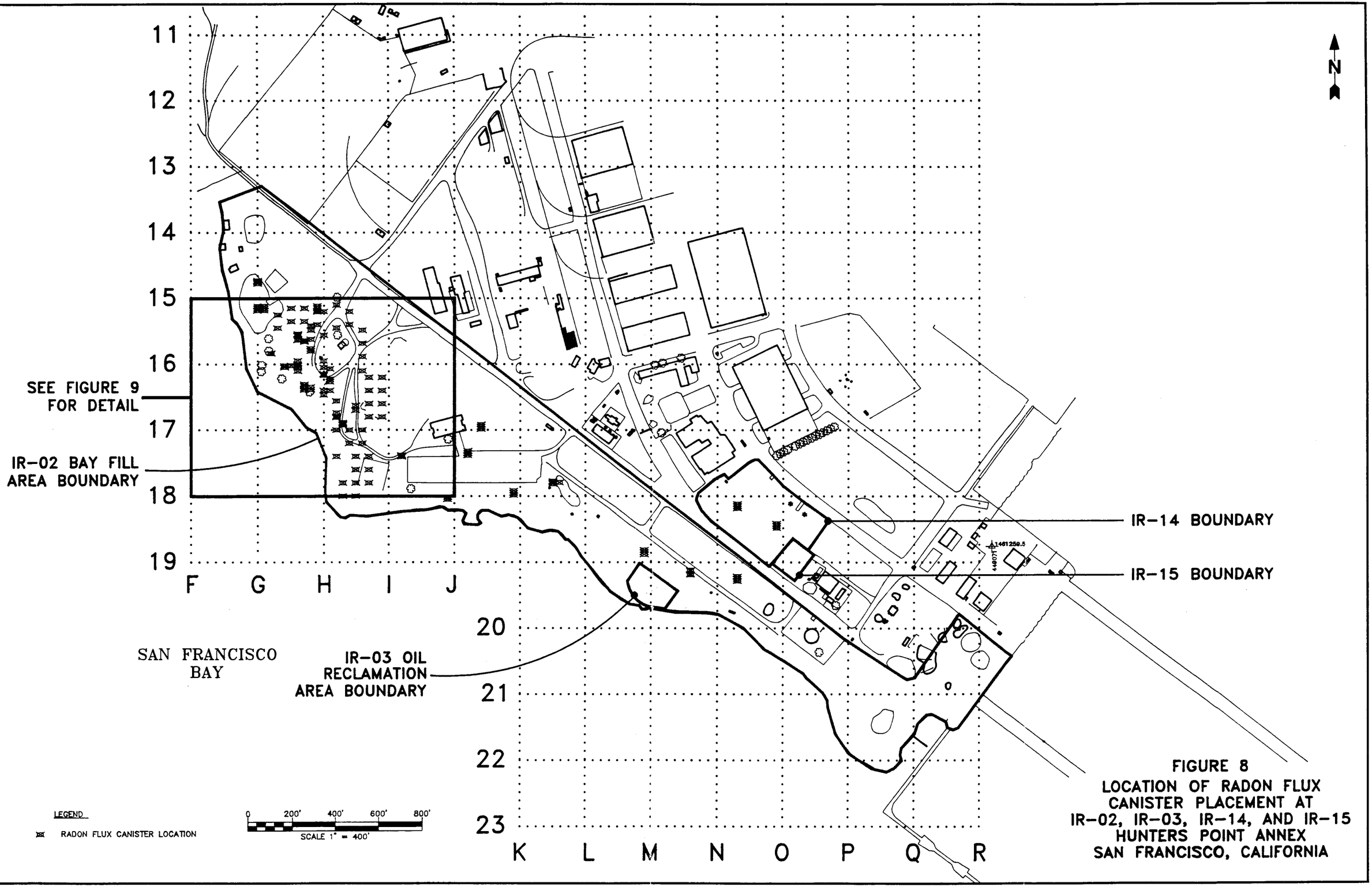

FIGURE 8
LOCATION OF RADON FLUX
CANISTER PLACEMENT AT
IR-02, IR-03, IR-14, AND IR-15
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

APPROXIMATE MEAN HIGH TIDE

EXTENT OF INVESTIGATION INTO BAY

APPROXIMATE MEAN LOW TIDE

APPROXIMATE LOCATION OF 1948 SHORELINE

AREA UNSURVEYED DUE TO DENSE VEGETATION

TRAIL

FENCE

CONC

600

PARKING

SAN FRANCISCO BAY

EXTENT OF INVESTIGATION INTO BAY

MATCH LINE FOR FIGURE 11

LEGEND

00 RADON FLUX CANISTER LOCATIONS AND RADON FLUX LEVELS $pCi \cdot m^{-2} \cdot s^{-1}$

SCALE 1" = 100'

FIGURE 9
LOCATION OF RADON FLUX CANISTER PLACEMENT SURROUNDING GRID COORDINATE H.00.00,16.00.00 AT IR-02
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

4.6.3 IR-03

No anomalous locations were found during the surface walkover gamma survey, therefore no radon flux canisters were placed.

4.6.4 IR-07

Five radon flux canisters were placed in and around an anomaly (M.06.00, 3.01.15, soil sample NAI2124) in the paved parking area. Figure 10 shows the radon flux canister placement locations at IR-07.

4.6.5 IR-14

Ten radon flux canisters were placed in two subgrid locations (N.03.00, 18.01.00 and N.09.00, 18.04.00). Figure 8 shows the radon flux canister placement locations at IR-14.

4.6.6 IR-15

No radon flux canisters were placed in IR-15 as no anomalous gamma activity was reported.

4.6.7 PA-18

No radon flux canisters were placed in PA-18 as no anomalous gamma activity was found.

4.6.8 PA-19

No radon flux canisters were placed in PA-19 as no anomalous gamma activity was found.

4.7 GROUNDWATER AND BAY WATER SAMPLING

Nine water samples were collected from existing groundwater wells between February 7, 1992 and February 12, 1992 to evaluate the extent of alpha, beta, and gamma emitting radionuclide contamination in groundwater at HPA. A total of two Bay water samples were collected from two tidal monitoring stations located at HPA. All samples were analyzed for gross alpha and beta activity. The samples were also analyzed using gamma spectroscopy to identify gamma emitting radioisotopes. Potassium-40 (^{40}K) concentrations (a natural contributor of significant beta activity) were determined by atomic absorption spectroscopy.

SAN FRANCISCO
BAY

N

J K L M N O

2

3

4

5

IR–07 SUBMARINE BASE AREA BOUNDARY

PA–18 BOUNDARY

1459000
454000

1460000
454000

453000
1459000

453000
1460000

FENCE LINE

DONAHUE STREET

916

0.00
0.05
0.06
0.29
0.07

LEGEND

0.07 RADON FLUX CANISTER LOCATIONS AND RADON FLUX LEVELS $pCi \cdot m^{-2} \cdot s^{-1}$

916 BUILDING 916 – "DAGO MARY'S"

0 100' 200' 300' 400'
SCALE 1" = 200'

FIGURE 10
LOCATION OF RADON FLUX CANISTER PLACEMENT AT IR–07 HUNTERS POINT ANNEX SAN FRANCISCO, CALIFORNIA

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Six groundwater wells in IR-02 were sampled including MWB-1, MWB-2, MWB-3, MW127B, MW175A, and MW179A.

In addition, MW20A1 in IR-07, MW38A in IR-09, and MW13A2 in IR-10 were also sampled. Sample collection locations were based upon laboratory results from previous groundwater sampling and upon limited knowledge of the groundwater flow characteristics.

The wells in IR-02 were sampled based primarily upon the results of previous gross alpha and beta analysis of water samples from these wells. There were three exceptions to this approach. The first exception was IR02MW127B, installed in 1992, which did not exist during the time of the previous round of water sampling. IR02MW127B was selected for sampling because it was located in the relative center of the large anomalous area that surrounds grid coordinate H.00.00 by 16.00.00. Monitoring wells IR09MW138A and IR10MW13A2 were also not previously sampled for gross alpha and beta activity. IR09MW138A was selected for sampling since it is located in the geographical center of HPA and was thought to be the least influenced by potential radioactive contamination and by tidal changes. IR10MW13A2 also was not previously sampled for radioactivity but was selected due to its lessened potential influence by radioactive contamination and its representative status of a tidally-influenced, saline well. The same analytical protocol for determination of gross alpha and beta was used for the two tidal station samples and for the groundwater samples.

4.8 DOWNHOLE GAMMA RADIATION SURVEY

A downhole gamma radiation survey was performed inside the casings of the same nine wells from which groundwater samples were collected. The maximum depth of the wells was 27 feet below ground surface (bgs). An Eberline PRS-1 ratemeter/scaler with a 2-inch by 2-inch lead-shielded NaI gamma scintillation detector was lowered into the well casing after the well was pumped as dry as possible. The detector was lowered to the water level and the gamma count rate recorded at 1-foot intervals in CPM as the detector was retrieved from the casing.

The water recharged many of the wells so quickly that only 5 to 12 feet of well depth could be surveyed without immersion of the gamma detector and subsequent loss of detector operation. Sampling of the subsurface material was not possible since all well installations were completed before the survey was performed.

The detector shielding consisted of a 1/2-inch lead sheet around a photomultiplier tube housing and a 1/4-inch lead plate on the bottom of the side of the detector. Some of the casings were not of sufficient inside diameter to accept the 2-inch by 2-inch detector and were logged with

a 1-inch by 1-inch NaI gamma scintillation detector. The decrease in size of the detector resulted in lower counts overall, but still provided information about changes in gamma activity.

4.9 CURSORY SURVEYS

The Naval Radiological Defense Laboratory (NRDL) was established in 1946 and later was designated to study the effects of nuclear weapons and appropriate counter measures. During its most active years until 1969 when it was disestablished, NRDL occupied approximately 28 sites and buildings. Due to limited information available about NRDL sites at the time cursory surveys were performed, only 4 buildings and sites associated with the NRDL were evaluated during the SCRS.

Cursory surveys of NRDL Buildings 351A, 701 (ruins), and 816, and Dry Dock 4 were performed to determine if these sites exhibited elevated radioactivity. There were two types of radiation detection instruments used in the survey. A NaI gamma scintillation detector was used to investigate small changes in background gamma activity. Additionally, a thin window Geiger-Mueller detector was used to evaluate surface contamination by beta and gamma emitters. Both detectors were connected to ratemeters/scalers that displayed activity in CPM.

4.9.1 Building 351A (Formerly Building 364)

Building 351A was previously identified in Naval documents as Building 364, a former NRDL building. The Navy had reportedly radiologically decontaminated a portion of the building and released the area for unrestricted use at an unknown date. The building is currently leased to a metalsmith. A cursory beta/gamma survey using a thin window Geiger-Mueller detector and a cursory gamma scan using a 2-inch by 2-inch gamma scintillation detector was done inside the area to determine if the surface activity within the building is in compliance with current U.S. Atomic Energy Commission (USAEC) guidance of 5000 disintegrations per minute per 100 square centimeters (dpm/100 cm^2) for fixed beta/gamma contamination (USAEC, 1974).

4.9.2 Building 701

Building 701 was demolished at an unknown date, but was identified on a map which suggested Building 701 had contained radioactive materials or instrumentation. The foundations of the building are not clearly visible, although a paved asphalt area in front could be original. Some gravel has been stockpiled in an area that appears to be bounded by the perimeter foundations; the original ground level is uncertain. A gamma walkover survey was done with a 2-inch by 2-inch NaI

gamma scintillation detector, and remaining concrete rubble and asphalt were scanned with a Geiger-Mueller beta/gamma detector.

4.9.3 Building 816

Building 816 previously housed a cyclotron and associated laboratories. The building is currently abandoned. In addition to the two previously mentioned survey instruments used in Buildings 351A and 701, a zinc sulfide scintillation detector was used to evaluate alpha contamination. An alpha, beta, and gamma surface contamination survey of the building was performed.

4.9.4 Dry Dock 4

Dry Dock 4 reportedly received ships for maintenance and repair that were either nuclear powered or had some potential to be contaminated with fission products from nuclear power or nuclear weapons testing operations. A cursory gamma survey was performed using a 2-inch by 2-inch NaI gamma scintillation detector along the floor and drainage trenches that traverse the length of the dry dock and in the sump for the main water pump pickup.

A cursory beta/gamma survey of the wood-cased concrete vessel support blocks with a thin window Geiger-Mueller beta/gamma detector was performed with emphasis on the support areas having contact with the ships. In addition, a liquid/sludge sample was collected from the main sump for analysis by gamma spectroscopy.

5.0 RESULTS

The purpose of this section is to summarize the results of the SCRS and compare them to normal background levels.

5.1 ESTABLISHMENT OF BACKGROUND VALUES

Twelve background locations consisting of representative geologic units were chosen on the HPA facility for determination of gamma activity. Eight locations were on soil areas where soil samples were collected. Three of these locations were on the southeast cut-bank slope of the northwest hill, which accommodates the former offices and quarters area of HPA. The hill area was chosen as it is likely to be representative of the material removed from the area and placed as fill

in the lower areas of HPA. The remaining background sampling sites were located over paved areas surrounding the northwest hill.

Gamma activity also was determined at four locations on asphalt-paved streets on or near the hill area where Geiger-Mueller beta/gamma detector measurements also were taken. Soil samples were not collected from these four locations. Figure 5 shows the twelve locations where background gamma activity and exposure was determined.

Gamma exposure rates ranged from 4.4 to 9.5 microRoentgens per hour (μR/hr) with an average of 7.8 μR/hr using the Reuter/Stokes PIC. Average gamma CPM on surface contact ranged from 2,120 to 10,220 CPM and averaged 7,490 CPM using the 2-inch by 2-inch NaI gamma scintillation detection. The Geiger-Mueller counts ranged from 49.6 CPM to 53.4 CPM and averaged 52.0 CPM. The differences in CPM between the NaI scintillation detector and the Geiger-Mueller detector are attributable to the inherent difference in efficiencies for gamma energies for each instrument.

5.2 SURFACE WALKOVER GAMMA SURVEY RESULTS

The surface walkover gamma survey conducted over the landfill areas was performed over each 30-foot subsector. Using a walkover technique to ensure that each subsector was entirely surveyed, the detector was suspended approximately 1 inch from the ground surface. The operator moved the detector back and forth across his path, approximately 2 feet wide, while walking in a rectangular grid pattern until the entire subsector was covered. The detector was connected to an Eberline PRS-1 ratemeter/scaler used in the ratemeter mode that displayed response in CPM.

As described in Section 4.3, the background gamma activity for the purposes of the walkover survey was established for each 30-foot by 30-foot grid square.

5.2.1 IR-01

Walkover gamma surveys located four anomalous areas with elevated readings within IR-01 that indicated the presence of gamma emitting materials, or ^{226}Ra-containing materials. Figure 11 shows the locations of radioactive point source anomalies at IR-01. Four discrete anomalies were located in subgrid location B.05.00, 13.01.00, with a maximum activity of 345,000 CPM. Soil sample NAI2118 was taken at this location where a solidified rock/slag material was observed at 5 inches laterally from the soil sample.

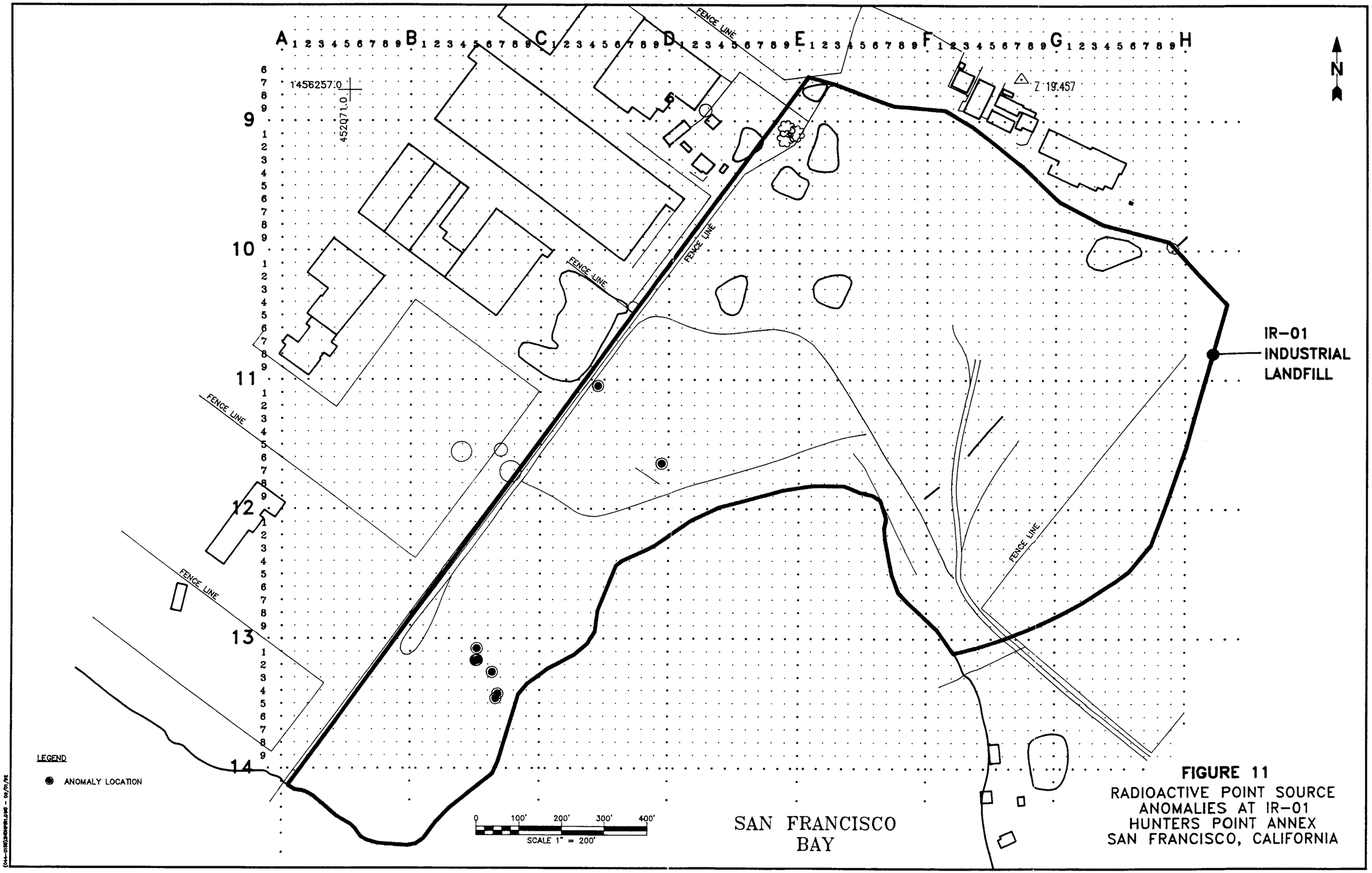

FIGURE 11
RADIOACTIVE POINT SOURCE
ANOMALIES AT IR-01
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

One anomaly was located in subgrid location B.06.00, 13.04.00 that had an activity of 45,000 CPM, but was not sampled due to hindered access. One anomaly with an activity of 45,000 CPM was located at C.04.05, 11.00.25, but due to rubble in the area soil, sampling efforts were hindered and the source of activity could not be retrieved. One anomaly reporting 44,000 CPM was located at subgrid location C.09.17, 11.06.28 where ^{226}Ra-containing material was removed during sampling of NAI2059. These two anomalies were found in the lowland area to the south and two additional areas were identified near the shoreline.

Several granite blocks and sections of granite curbing, located in the eastern area of IR-01, were observed to have elevated gamma activity. This is not unusual, since granite rocks are composed of minerals including feldspar and mica that contain up to 3.5 percent potassium, of which about 0.01 percent is typically radioactive. Granitic rocks can also be enriched in uranium and thorium relative to other types of rocks composing the earth's crust. Soil samples were taken for confirmation of this assumption.

Grouted boreholes located near the northwest property corner had gamma activity greater than 50 percent above the general area and were investigated with the placement of radon flux canisters and collection of soil samples. Later, it was determined that the sunken grout allowing the detector to be placed below ground surface and surrounded by soils, had influenced the geometry. One soil sample was collected from subgrid location E.04.16, 08.08.22.

The sand-filled berm and other stockpiled sand areas throughout IR-01 exhibited gamma activity greater than 50 percent above the general area activity levels of the subgrid locations, and, in some instances, were greater than 50 percent above the established site background levels. Soil samples were collected in several areas of this sand, and radon flux canisters were placed at numerous locations in the same areas.

5.2.2 IR-02

Walkover gamma surveys located and defined a large anomalous area around grid coordinate H.00.00, 16.00.00 that measures approximately 600 feet by 600 feet. The H.00.00, 16.00.00 grid coordinate area was treated as one large anomaly and received intensive soil sampling and radon flux canister placement. Within this anomalous area, which extended into the Bay sediment, 375 anomalies were located that had gamma count rates from 50 percent above background to 1,300,000 CPM.

In several instances, ^{226}Ra-containing materials were observed on the ground surface. Where the soil was sampled and the source of gamma activity was visible and retrievable, the sources were removed and placed in the radioactive materials storage structure in Building 414.

Ten anomalies were located outside of the grid coordinate H.00.00, 16.00.00 anomalous area within IR-02 as shown in Figures 12 and 13, maps of the locations of radioactive point source anomalies at IR-02. An anomaly at subgrid location K.05.00, 17.07.00 was identified as slag material adhered to the side of a large rock, approximately 30 inches by 30 inches by 30 inches. All other anomalies were located on or below the surface. Soil sampling and radon flux canister placement was done at all anomalies located outside the area surrounding grid coordinate H.00.00, 16.00.00 except at Berths 30 and 35 and on pavement. Figure 14 is a map of the location of radioactive point source anomalies surrounding grid coordinate H.00.00, 16.00.00 at IR-02.

5.2.3 IR-03

Walkover gamma surveys reported no anomalous areas within IR-03. Two subgrid locations L.06.00, 18.06.00 and L.09.00, 18.08.00 north of IR-03 exhibited elevated gamma activity in black-colored sand. Soil samples were collected at both locations and radon flux canisters were placed in subgrid location L.09.00, 18.08.00.

5.2.4 IR-07

Walkover gamma surveys located anomalous areas related to light brown-colored sand exposed on slopes at the Donahue Street boundary. Gamma activities exceeding the site background value by more than 50 percent and general area gamma activity levels were noted. No anomalies were noted on the shoreline. Figure 15 shows the location of radioactive point source anomalies at IR-07.

5.2.5 IR-14

Walkover gamma surveys located anomalous areas containing black-colored sand scattered throughout the IR-14 area. This material exceeded the general area gamma activity level by 50 percent. A combination safe measuring approximately 18-inches by 18-inches by 18-inches was found to have gamma activity on its door. Further investigation revealed that the combination dial and handle have fixed alpha contamination above release guidelines established by USAEC.

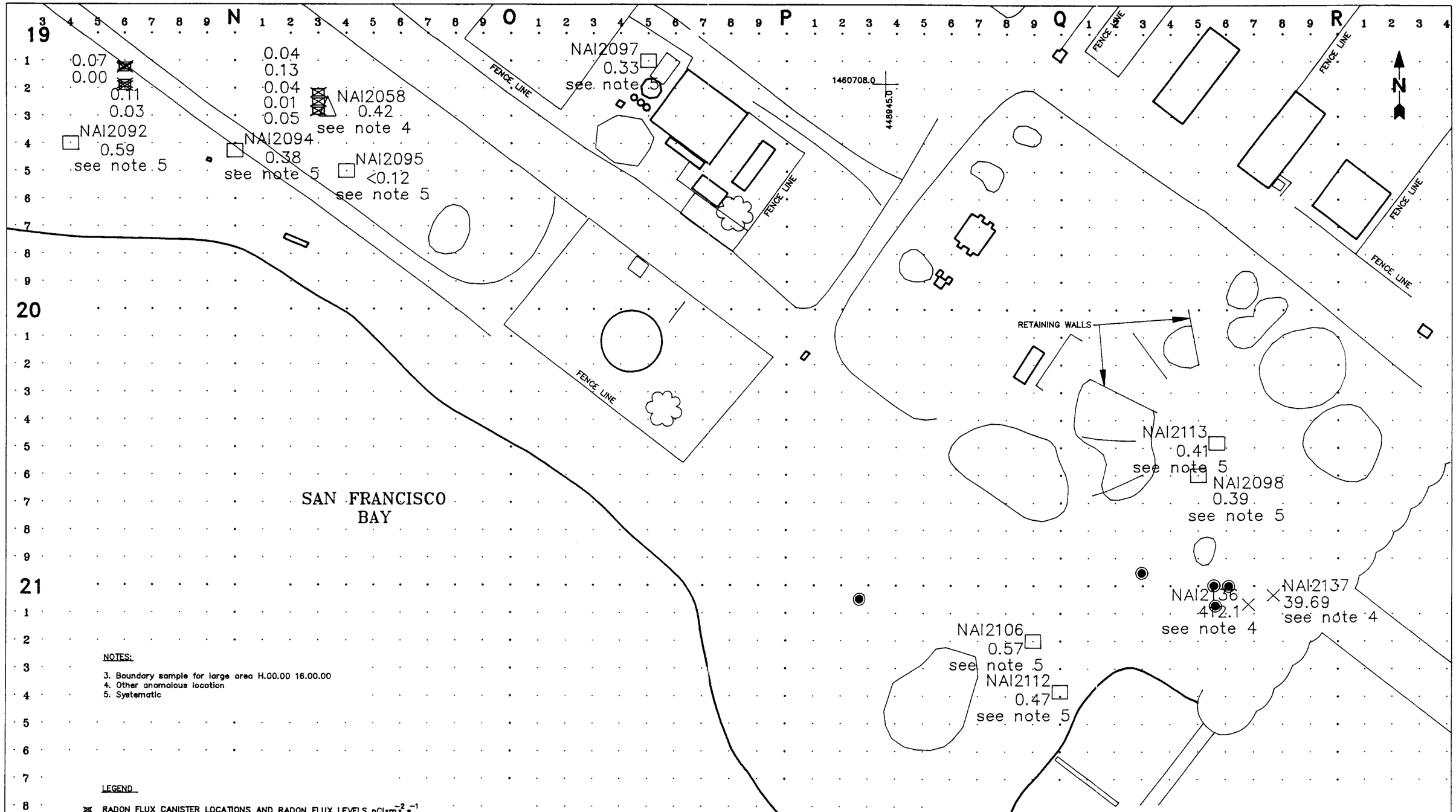

FIGURE 12

LOCATION OF RADIOACTIVE POINT SOURCE ANOMALIES, SOIL SAMPLE COLLECTION AND RADON FLUX CANISTER PLACEMENT AT THE SOUTHEASTERN END OF IR-02 HUNTERS POINT ANNEX, SAN FRANCISCO, CALIFORNIA

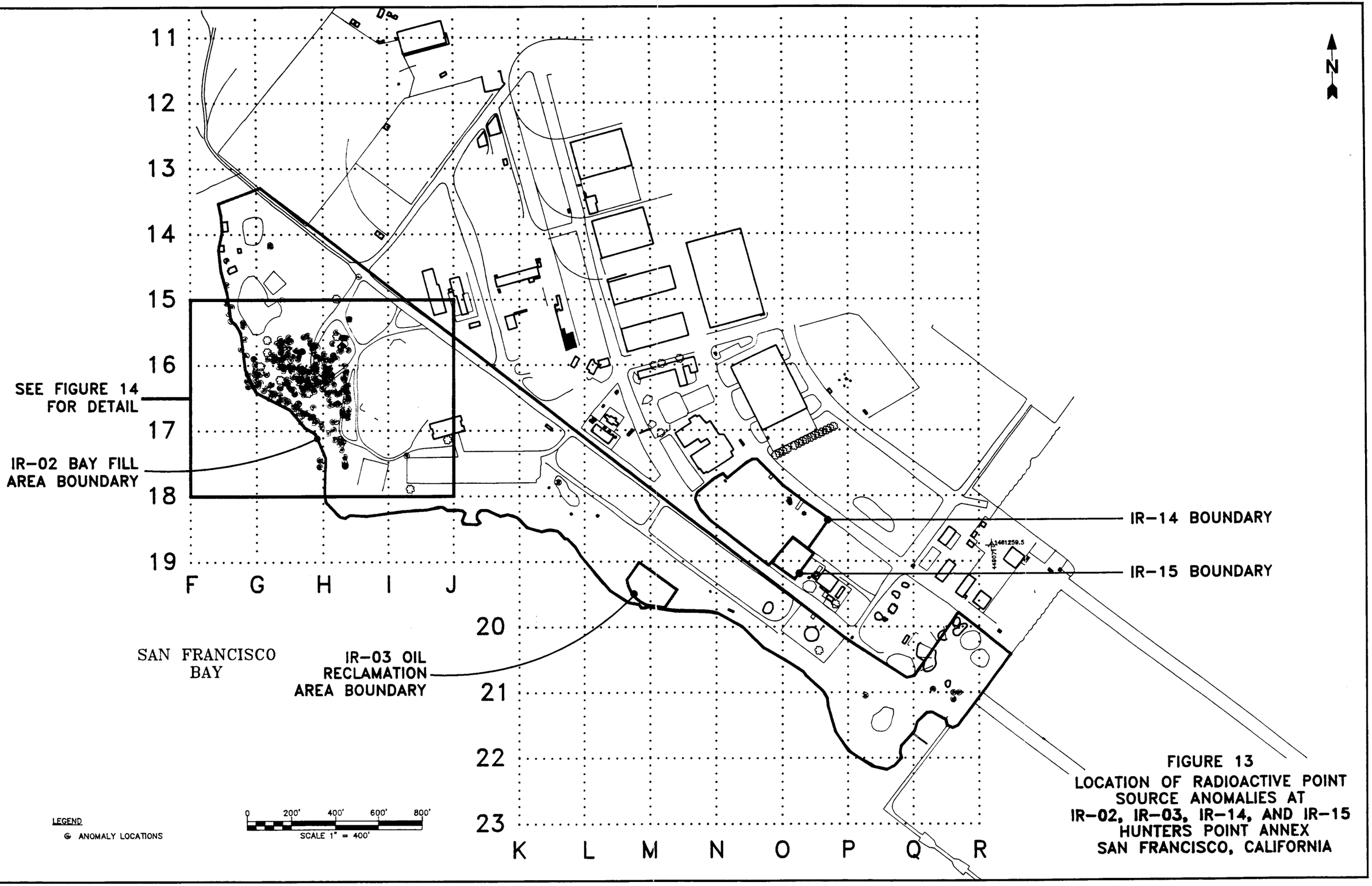

FIGURE 13
LOCATION OF RADIOACTIVE POINT SOURCE ANOMALIES AT
IR-02, IR-03, IR-14, AND IR-15
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

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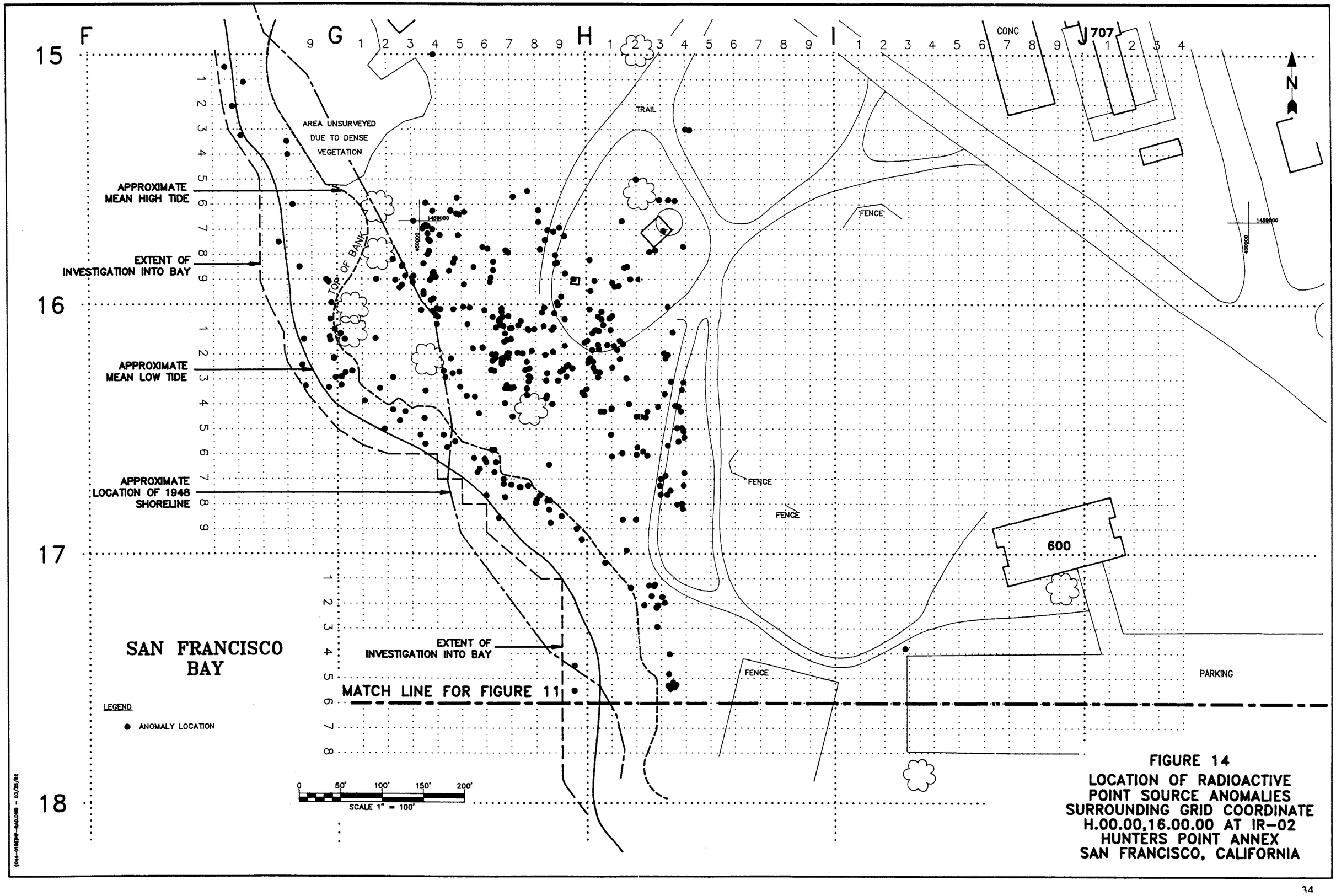

FIGURE 14
LOCATION OF RADIOACTIVE POINT SOURCE ANOMALIES SURROUNDING GRID COORDINATE H.00.00,16.00.00 AT IR-02 HUNTERS POINT ANNEX SAN FRANCISCO, CALIFORNIA

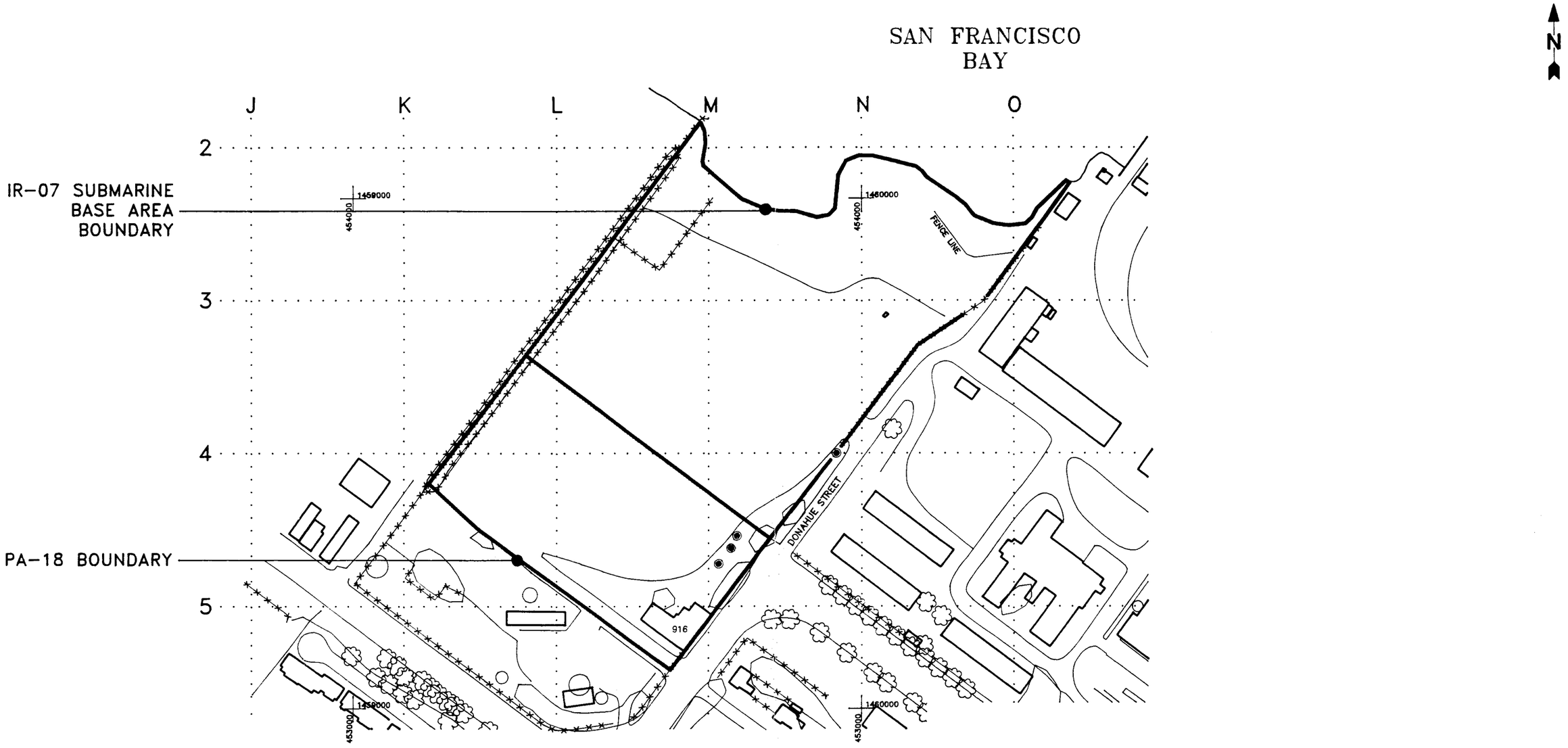

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FIGURE 15
LOCATION OF RADIOACTIVE POINT SOURCE ANOMALIES AT IR-07 AND PA-18 HUNTERS POINT ANNEX SAN FRANCISCO, CALIFORNIA

The fixed alpha activity found on the safe door was 59,000 dpm/100 cm^2. The contents, previous location, and intended use of the safe are unknown. Removable contamination was not found. Figure 13 shows the location of radioactive point source anomalies at IR-14.

Federal agencies associated with radiation safety have adopted contamination limits for both removable and fixed contamination on surfaces that personnel may come in contact with. Fixed contamination refers to that component of contamination which cannot be removed by wiping the surface and transferring that contamination to the wipe. Removable contamination can be transferred to a wipe by contact with the surface. These contamination limits restrict the movement and use of any radioactive material, or item, that exceeds the specified guideline. The fixed alpha release criteria for ^{226}Ra, as established by the USAEC, is 300 dpm\100 cm^2. One disintegration is the emission of one photon or particle from a radioisotope. Disintegration rate is determined by dividing the count rate by the efficiency of the detector for that specific radioisotope.)

5.2.6 IR-15

The walkover gamma surveys identified no anomalous areas in IR-15.

5.2.7 PA-18

The walkover gamma surveys located several anomalous areas related to light-brown colored sand exposed along the boundary and side-slopes of Donahue Street extending from the intersection with IR-07 to the rear of Dago Mary's Restaurant. Gamma activities at this location exceeded both the established site background and general area activity by more than 50 percent. Two soil samples, NAI2111 and NAI2122 were collected in these areas. Figure 15 shows the location of radioactive point source anomalies at PA-18.

5.2.8 PA-19

The walkover gamma surveys located no anomalous areas within PA-19.

5.3 RADON FLUX CANISTER RESULTS

The radon flux rate observed for soils and uranium mine tailings varies as a function of several factors. One of these factors is the ^{226}Ra content of the material being tested. The ^{222}Rn flux rate of typical soils is approximately 0.45 $pCi \cdot m^{-2} \cdot sec^{-1}$ as presented in NCRP Report No. 97 (1988), Measurement of Radon and Radon Daughters in Air. In contrast, the ^{222}Rn flux rate from the

inactive or uncovered uranium mill tailings impoundment near Shiprock, New Mexico, averaged 750 $pCi \cdot m^{-2} \cdot sec^{-1}$ (Haywood et al., 1979).

The National Emission Standard (40 CFR 61) for ^{222}Rn flux from uranium mill tailings and phospho-gypsum operations is 20 $pCi \cdot m^{-2} \cdot sec^{-1}$. The amount of soil compaction affects the amount of ^{222}Rn that can be released from the soil. Because hard packed soils tend to have less transmissivity to gasses, radon flux rates tend to be lower at these locations. Atmospheric pressure changes also affect radon flux rates. Low pressure systems associated with storms tend to increase ^{222}Rn release from soils. Additionally, decreased soil moisture also tends to increase release of ^{222}Rn from soils.

At HPA, the radon flux rates generally were representative of those found in ordinary soil. Background radon flux rates ranged from 0.01 to 1.12 $pCi \cdot m^{-2} \cdot sec^{-1}$. With one exception out of 370 canisters placed, significantly elevated radon flux rates were only observed when charcoal canisters were placed directly on top of recognizable gamma radiation anomalies. Numerous radon flux canisters were placed within a few feet of recognizable ^{226}Ra point sources. With one exception, these measurements show that radon flux rates are essentially normal in the IR areas except when a canister is placed within 1 foot or so of a recognizable point source. Table 1 shows the results of radon flux rate measurements.

Some of the radon flux canisters listed in Table 1 have the same sample ID number. Following radon flux counting in the laboratory, each canister was refilled with new activated carbon and readied for reuse in the field. Because each canister has a specific number permanently assigned to it, duplication of sample ID numbers occurred when a canister previously used in the field anevent. Approximately 10 of the total 137 radon flux canister ID numbers were used at HPA twice. Radon flux rate results having duplicate sample ID numbers are distinguishable by the location coordinates that identify where radon flux was sampled and the date samples were collected.

5.3.1 IR-01

Two grid areas where the source materials remained in the soil (B.05.04, 13.01.24; soil sample NAI2118; and C.04.08, 11.00.24; no soil sample taken) reported a radon flux rate of 8.97 and 1.42 $pCi \cdot m^{-2} \cdot sec^{-1}$. At one location (C.09.17, 11.06.28; soil sample NAI2059) where the ^{226}Ra-containing material was removed along with the soil sample, the radon flux canisters surrounding the sample location showed a radon flux rate measurement less than 0.2 $pCi \cdot m^{-2} \cdot sec^{-1}$.

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)

(Sheet 1 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
0132	D.09.05, 09.06.05	0.06
0145	D.08.25, 09.03.25	0.15
0174	BKGRD - 5-N	0.01
0203	D.08.25, 09.05.05	0.18
0205	B.08.15, 12.07.15	0.10
0234	E.04.26, 08.08.26	0.18
0248	C.00.05, 12.09.22	0.19
0257	B.08.25, 12.07.05	0.03
0260	D.08.05, 09.05.25	0.12
0265	E.03.24, 08.08.21	0.00
0266	D.09.05, 09.04.05	0.25
0298	X.05.05, 17.00.25	0.04
0303	H.00.08, 15.09.15	74.96
0306	G.06.00, 16.01.01	0.06
0312	G.07.03, 15.06.18	12.25
0327	D.08.25, 09.05.25	0.00
0346 TRIP BLANK	X.00.00, 02.00.00	0.00
0371	A.03.15, 13.09.15	0.30
0378	G.08.05, 15.06.07	0.86
0387	BKGRD - 4-E	0.21
0411	E.02.05, 09.01.05	0.42
0417	H.02.00, 17.00.00	0.03
0422(A)	H.07.08, 17.04.00	3.55
0422(B)	G.06.11, 16.00.16	3.55
0429 TRIP BLANK	X.00.00, 02.00.00	0.00
0460 TRIP BLANK	X.01.25, 01.01.25	0.00
0565	G.06.07, 16.00.00	0.47

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 2 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
0580(A)	G.09.00, 15.04.00	0.00
0580(B)	N.03.25, 19.02.05	0.00
0589(A)	M.05.25, 03.01.25	0.10
0589(B)	H.07.05, 16.04.00	0.10
0598(A)	N.09.05, 18.04.25	0.07
0598(B)	H.04.00, 15.04.00	0.00
0599	G.07.20, 16.03.02	6.95
0601	H.02.00, 15.04.15	0.03
0602	D.09.15, 09.06.15	0.00
0606	E.08.05, 11.01.05	0.16
0609 TRIP BLANK	X.20.00, 23.00.00	0.01
0609	H.00.19, 16.04.20	0.19
0612	C.00.25, 12.09.05	0.43
0620(A)	H.02.08, 17.04.00	0.31
0620(B)	M.05.25, 03.01.15	0.31
0623(A)	H.00.10, 16.01.20	0.99
0623(B)	M.05.25, 03.01.05	0.99
0625 TRIP BLANK	X.00.00, 01.00.00	0.09
0647	C.00.05, 12.09.05	0.02
0690(A)	H.07.00, 16.02.00	0.14
0690(B)	M.05.15, 03.01.15	0.14
0708	C.09.17, 11.07.04	0.08
0722	C.00.05, 12.03.25	0.08
0726	E.04.04, 08.08.25	0.16
0730	H.02.19, 16.08.02	0.31
0765	G.04.08, 16.00.14	0.16
0767	G.01.05, 15.01.25	0.28
0768	G.07.15, 16.03.20	0.55

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 3 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
0775(A)	H.02.10, 16.05.18	0.62
0775(B)	H.03.00, 17.08.00	0.62
0811	G.07.00, 15.03.15	0.10
0812 TRIP BLANK	X.00.00, 03.00.00	0.03
0825	G.08.03, 15.07.20	1.77
0859	H.06.00, 15.08.25	0.25
0869	D.08.05, 09.05.05	0.02
0907(A)	H.06.15, 17.02.00	0.08
0907 (B)	X.15.15, 24.15.15	0.08
0937	H.06.00, 15.06.25	0.05
0937	N.03.05, 19.02.05	0.04
0938	H.06.00, 16.01.00	0.03
0974	D.09.25, 09.04.25	0.19
0978	H.02.25, 16.07.28	5.81
0983(A)	H.01.15, 16.02.08	9.87
0983(B)	H.05.05, 17.06.00	9.87
1000	H.01.00, 16.00.21	0.17
1002	D.08.05, 09.09.05	0.09
1053	H.00.18, 16.01.15	0.00
1060	H.02.00, 15.01.00	0.08
1064	H.05.00, 16.06.08	0.40
1069	E.02.05, 09.04.25	0.00
1072	L.09.05, 18.08.05	0.00
1073	B.08.05, 12.07.05	0.00
1074	B.07.05, 12.08.25	0.20
1075	H.00.20, 15.02.00	0.06
1077	D.01.05, 11.05.25	0.24

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 4 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
1081	H.04.00, 17.02.00	0.07
1085	D.09.25, 09.06.02	0.08
1098	G.08.12, 16.03.26	0.22
1110	BKGRD - 5	0.00
1112	G.08.00, 15.08.00	0.25
1115(A)	G.05.00, 15.03.15	0.12
1115(B)	H.07.00, 17.08.00	0.02
1116(A)	H.07.05, 17.06.00	0.09
1116(B)	H.06.00, 15.04.25	0.09
1122	B.07.25, 12.08.25	0.02
1127	C.05.25, 11.05.25	0.10
1128	H.02.00, 16.05.18	32.47
1131	B.08.25, 12.09.25	0.00
1142	A.03.25, 13.09.05	0.29
1143	G.05.00, 15.01.15	0.00
1145	C.00.15, 12.03.15	0.24
1147	F.03.25, 12.03.05	0.22
1148 TRIP BLANK	X.02.25, 01.01.25	0.00
1158	E.02.05, 09.01.25	0.14
1159	A.05.15, 13.09.15	0.20
1161(A)	H.02.20, 16.07.12	0.80
1161(B)	H.05.00, 17.08.00	0.80
1167	D.01.25, 11.05.05	0.13
1174	C.01.05, 12.04.25	0.11
1182	E.02.25, 09.01.05	1.39
1183	D.01.25, 11.05.25	0.25
1186	D.09.05, 09.06.25	0.00

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)

(Sheet 5 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
1192	I.02.15, 17.03.25	0.15
1197	C.01.20, 12.04.22	0.03
1203	G.01.05, 12.06.25	0.23
1206	B.08.05, 12.09.05	0.10
1208	C.05.15, 11.05.15	0.26
1217	H.03.15, 16.09.03	0.49
1219	D.01.15, 11.05.15	0.14
1234	D.01.05, 11.05.05	0.07
1242	H.06.00, 17.00.00	0.04
1244	G.01.25, 12.06.05	0.25
1253	C.00.25, 12.09.25	0.11
1260	A.03.05, 13.09.25	0.13
1263	E.02.25, 09.04.05	0.05
1264	G.02.27, 15.08.10	0.79
1270	A.03.05, 13.09.05	0.09
1271(A)	H.05.08, 17.04.00	0.10
1271(B)	G.03.00, 15.04.15	0.10
1278	BKGRD - 7	0.05
1280	G.01.05, 12.06.05	0.00
1288(A)	H.01.17, 16.02.20	0.98
1288(B)	M.06.10, 03.01.15	0.98
1292	H.03.03, 16.09.01	0.56
1293	B.08.07, 12.05.20	0.00
1310	A.06.24, 14.00.20	0.23
1319	F.03.25, 12.03.25	0.24
1323	D.09.15, 09.04.15	0.09
1327	C.04.08, 11.01.00	0.03

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)

(Sheet 6 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
1335	B.00.05, 13.00.05	0.03
1349	B.08.05, 12.09.25	0.05
1354	F.03.15, 12.03.15	0.13
1356	G.07.00, 15.01.15	0.10
1357	B.07.05, 12.08.05	0.04
1365	G.05.27, 16.00.06	16.03
1368	H.01.21, 16.02.10	0.05
1370	C.05.25, 11.05.05	0.11
1371	H.03.07, 16.09.07	0.26
1376	F.03.05, 12.03.05	0.07
1378	G.06.20, 15.05.15	47.42
1381	E.03.25, 09.03.25	0.06
1385	H.00.20, 16.04.00	12.49
1387	B.05.04, 13.01.24	8.97
1394	H.00.26, 16.01.17	2.27
1402	B.05.28, 13.01.20	0.15
1403(A)	H.04.00, 15.02.00	0.00
1403(B)	H.05.00, 18.00.00	0.00
1406	C.01.05, 12.04.05	0.05
1416	H.09.05, 16.04.00	0.03
1420	G.02.25, 12.02.05	0.04
1424	E.02.15, 09.01.15	0.09
1427	C.00.15, 12.09.12	0.07
1431	G.06.04, 15.05.20	0.45
1440	A.06.05, 14.00.25	0.17
1441	A.06.15, 14.00.15	0.24
1442	B.05.25, 13.01.05	0.11

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 7 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
1454	A.06.05, 14.00.06	0.35
1456	G.01.15, 12.06.15	0.13
1462	A.03.25, 13.09.25	0.30
1468	A.05.05, 13.09.05	0.17
1471	H.09.00, 16.02.00	0.13
1473	G.06.00, 15.09.14	0.22
1479	G.02.05, 12.02.25	0.14
1491	F.04.05, 12.03.05	0.43
1494	G.01.25, 12.06.25	0.22
1500(A)	G.03.00, 15.02.15	0.21
1500(B)	H.03.00, 18.00.00	0.00
1507	J.09.25, 17.09.05	0.02
1512	C.09.17, 11.06.28	0.10
1515	B.00.05, 13.00.25	0.15
1516	H.00.27, 16.00.15	7.20
1522	G.06.19, 16.00.06	3.12
1564	E.02.25, 09.04.25	0.09
1565	B.07.25, 12.08.05	0.13
1568	D.09.25, 09.04.05	0.26
1588	B.08.25, 12.07.25	0.04
1595	C.04.14, 11.00.24	0.17
1605	B.08.25, 12.09.05	0.06
1613	C.04.08, 11.00.18	0.11
1624	G.06.02, 15.06.10	0.26
1631	G.02.15, 12.02.15	0.08
1632	C.05.05, 11.05.25	0.16
1642	A.06.24, 14.00.08	0.20

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 8 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
1652	B.08.05, 12.07.25	0.04
1656 TRIP BLANK	X.00.00, 01.00.00	0.00
1670	A.05.25, 13.09.05	0.07
1683	C.00.25, 12.03.05	0.11
1689	B.08.25, 12.05.25	0.08
2002	D.09.25, 09.08.05	0.04
2003	C.01.25, 12.04.05	0.09
2004	C.06.25, 11.02.05	0.00
2008	H.09.06, 16.08.00	0.17
2010	D.09.25, 09.08.05	0.01
2011	G.07.14, 16.03.27	0.02
2013	H.09.12, 16.06.00	0.11
2015	G.02.05, 12.05.25	0.15
2016	B.08.15, 12.09.15	0.10
2017	G.09.00, 15.02.00	0.14
2019	H.03.09, 16.08.26	1.75
2020	G.02.05, 12.05.05	0.00
2021	G.08.15, 16.03.14	0.86
2022	C.04.08, 11.00.24	1.42
2023	C.07.25, 11.01.25	0.35
2024	D.09.05, 09.04.25	0.23
2025	F.04.25, 12.03.05	0.02
2028	J.02.25, 17.03.25	0.00
2029	E.03.05, 09.03.25	0.24
2030	A.05.05, 13.09.25	0.39
2031	C.00.25, 12.03.25	0.19
2033	B.00.20, 13.00.05	0.10

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 9 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
2036	H.07.06, 16.08.00	0.12
2037 TRIP BLANK	X.00.00, 03.00.00	0.09
2040	J.09.15, 17.09.15	0.00
2042	C.04.02, 11.00.24	0.04
2044	I.02.21, 17.03.25	0.48
2047	J.04.15, 16.09.15	0.05
2049	B.00.25, 13.00.25	0.17
2050	H.05.00, 16.07.00	0.41
2051	G.04.04, 16.00.07	2.62
2054	H.04.00, 17.00.00	0.09
2055	D.08.05, 09.09.25	0.12
2057	E.04.05, 09.02.25	0.08
2058	J.02.05, 17.03.25	0.00
2059	C.05.05, 11.05.05	0.18
2061	A.05.25, 13.09.25	0.17
2062	G.01.15, 15.01.15	0.29
2063	B.07.15, 12.08.15	0.05
2084	N.09.25, 18.04.25	0.09
2092	N.03.25, 19.02.25	0.05
2093	C.05.05, 11.03.25	0.32
2095	N.03.15, 19.02.15	0.04
2097	C.05.15, 11.03.15	0.27
2098	N.09.25, 18.04.05	0.04
2100	L.09.25, 18.08.05	0.04
2101	BKGRD - 1-E	0.04
2102	G.00.09, 14.07.15	0.12
2103	C.06.15, 11.02.15	0.30

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)

(Sheet 10 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
2104	D.08.15, 09.05.15	0.10
2105	M.06.05, 19.01.08	0.00
2107	G.00.05, 15.01.25	0.30
2108	G.00.25, 15.01.25	0.00
2109	G.01.25, 15.01.05	0.15
2110	E.03.05, 09.04.05	0.15
2111	C.05.25, 11.03.05	0.41
2112	B.00.15, 13.00.15	0.00
2113	B.08.05, 12.05.05	0.02
2114	G.06.08, 15.05.12	0.24
2117	C.07.05, 11.03.25	0.16
2118	C.07.15, 11.03.15	0.07
2119	E.08.05, 11.01.25	0.03
2120	E.03.15, 09.04.15	0.05
2121	G.00.22, 14.07.15	0.57
2124	G.08.25, 15.04.25	0.01
2125	C.05.05, 11.03.05	0.26
2126	D.08.15, 09.09.15	0.03
2128	G.07.08, 16.03.10	0.39
2129	G.09.05, 15.01.25	0.11
2131	BKGRD - 1-W	0.09
2132	D.08.25, 09.09.05	0.19
2133	N.03.25, 18.01.25	0.13
2134	J.02.15, 17.03.15	0.02
2135	H.00.20, 15.05.18	0.00
2136	G.06.25, 15.06.10	38.20
2137	B.05.15, 13.01.13	0.05
2138	D.08.15, 09.03.15	0.06

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)

(Sheet 11 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
2139	G.08.05, 15.04.05	0.04
2142	K.05.28, 17.07.22	0.05
2143	D.08.25, 09.03.05	0.09
2144	C.06.05, 11.02.05	0.23
2147	B.05.05, 13.01.05	0.24
2148	G.02.15, 12.05.15	0.12
2149	G.07.25, 15.06.13	0.06
2150	H.01.00, 16.04.00	0.35
2151	BKGRD - 3	0.23
2152	C.01.15, 12.04.15	0.07
2153	E.08.05, 11.02.05	0.11
2155	J.09.05, 17.09.25	0.02
2156	B.08.15, 12.05.15	0.00
2160	C.07.25, 11.03.05	0.01
2169	BKGRD - 3-W	0.29
2170	C.09.17, 11.06.22	0.17
2171	BKGRD - 3-E	0.27
2172	C.07.15, 11.01.15	0.11
2173	N.03.05, 18.01.05	0.14
2174	E.02.25, 09.01.25	0.22
2176	E.04.10, 08.08.19	0.09
2177	E.04.00, 08.08.15	0.01
2179	G.02.15, 15.08.11	10.96
2186	C.07.25, 11.03.25	0.08
2187	D.09.25, 09.06.05	0.06
2192	E.08.15, 11.01.15	0.22
2193	I.09.15, 18.00.15	0.03

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)

(Sheet 12 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
2194	N.09.15, 18.04.15	0.13
2195	J.09.25, 17.09.25	0.05
2196	G.00.15, 14.07.15	0.00
2198	N.03.05, 19.02.25	0.13
2200	N.09.05, 18.04.05	0.31
2201	C.06.25, 11.02.25	0.32
2202	F.03.05, 12.03.25	0.20
2203	D.08.05, 09.03.25	0.27
2204	I.02.15, 17.04.01	0.07
2206	BKGRD - 7-S	0.04
2207	BKGRD - 6	0.20
2209	E.03.05, 09.03.25	0.20
2211	E.04.05, 09.02.05	0.12
2213	C.05.25, 11.03.25	0.26
2214	E.03.15, 09.03.15	0.14
2215	E.02.15, 09.04.15	0.02
2220	BKGRD - 2	0.11
2224	BKGRD - 4-W	0.11
2225	G.09.25, 15.01.25	0.00
2227	L.09.15, 18.08.15	0.03
2229	K.05.22, 17.07.28	0.03
2231	I.02.09, 17.03.25	0.00
2233	E.03.25, 09.04.25	0.02
2239	BKGRD - 5-S	0.01
2273	B.08.25, 12.05.05	0.15
2274	H.07.12, 16.06.00	0.14

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)

(Sheet 13 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
2289	D.09.05, 09.08.25	0.07
2390	E.04.20, 08.08.20	0.08
2397	G.01.05, 15.01.05	0.31
2399	C.09.23, 11.06.28	0.18
2409	G.00.15, 14.07.22	0.19
2411	C.07.05, 11.03.05	0.18
2415	G.00.05, 15.01.05	0.28
2516	D.09.15, 09.08.15	0.15
2551	C.00.05, 12.03.05	0.24
2623	E.08.25, 11.02.05	0.06
3100	C.07.25, 11.01.05	0.26
3106	C.06.05, 11.02.25	0.34
3110	G.00.25, 15.01.05	0.20
3111	C.07.05, 11.01.05	0.00
3112	G.01.25, 15.01.25	0.18
3114	G.08.25, 15.04.05	0.00
3116	E.08.25, 11.02.25	0.14
3119	L.09.25, 18.08.25	0.04
3124	J.02.05, 17.03.05	0.01
3125	E.04.20, 08.09.02	0.09
3126	G.02.05, 12.02.05	0.20
3127	G.09.15, 15.01.15	0.13
3130	G.02.25, 12.02.25	0.04
3132	G.00.15, 14.07.09	0.07
3134	E.08.15, 11.02.15	0.04
3135 TRIP BLANK	X.04.25, 02.02.25	0.14
3136	E.04.15, 09.02.15	0.31

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 14 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
3138	K.05.28, 17.08.04	0.07
3141	G.02.05, 12.08.25	0.06
3142	F.04.05, 12.03.25	0.21
3147	K.06.04, 17.07.28	0.00
3148	G.02.05, 12.08.05	0.30
3150	E.04.00, 08.08.27	0.00
3151	E.08.05, 11.02.25	0.16
3154	E.08.25, 11.01.25	0.45
3157	G.02.25, 12.08.05	0.23
3161	D.09.05, 09.08.05	0.02
3162	I.09.25, 18.00.05	0.03
3163	M.06.05, 19.01.25	0.11
3164	G.02.25, 12.08.25	0.00
3170	M.06.25, 19.01.06	0.07
3171	E.08.25, 11.01.05	0.15
3172	F.04.25, 12.03.25	0.03
3173	M.06.26, 19.01.28	0.03
3178	F.04.15, 12.03.15	0.34
3179	G.02.15, 12.08.15	0.24
3182	J.04.25, 16.09.25	0.00
3185	C.07.05, 11.01.25	0.14
3188	E.04.25, 09.02.05	0.03
3189	BKGRD - 8-S	0.21
3190	E.03.25, 09.03.25	0.00
3193	BKGRD - 2-E	0.33
3194	E.04.25, 09.02.25	0.36
3197	E.04.10, 08.09.01	0.12

TABLE 1

SUMMARY OF RADON FLUX RATE RESULTS ($pCi \cdot m^{-2} \cdot sec^{-1}$)
(Sheet 15 of 15)

Canister ID Number	Canister Location	Radon Flux ($pCi \cdot m^{-2} \cdot sec^{-1}$)
3198	BKGRD - 6-E	0.04
3199	J.04.05, 16.09.25	0.05
3208	J.02.25, 17.03.05	0.03
3227	G.09.25, 15.01.05	0.11
3228	G.09.05, 15.01.05	0.05
3234	N.03.25, 18.01.05	0.08
3238	N.03.15, 18.01.15	0.15
3243	N.03.05, 18.01.25	0.09
3244	BKGRD - 8-W	0.10
3245	BKGRD - 1	0.10
3293	E.02.05, 09.04.05	0.00
3300	J.04.05, 16.09.05	0.00
3307	C.09.12, 11.06.28	0.08
3319	I.09.05, 18.00.05	0.05
3329	G.08.05, 15.04.25	0.06
3339	BKGRD - 8-N	0.02
3343	BKGRD - 8	0.16
3350	E.03.05, 09.04.25	0.01
3351	BKGRD - 6-W	1.12
3359	G.00.15, 15.01.15	0.14
3365	J.04.25, 16.09.05	0.03
3399	G.02.25, 12.05.25	0.29
4250	G.02.25, 12.05.05	0.08
4251	E.03.25, 09.04.05	0.12
4281	BKGRD - 4	0.17

Nine radon flux canisters were placed in the northwest corner around boreholes and provided measurements of radon flux rates less than 0.2 $pCi \cdot m^{-2} \cdot sec^{-1}$. None of the measurements exceeded 0.5 $pCi \cdot m^{-2} \cdot sec^{-1}$.

5.3.2 IR-02

In the large anomalous area at grid coordinate H.00.00, 16.00.00, the 25 canisters, placed directly on anomalies ranging in gamma activity from 24,000 CPM to 670,000 CPM, had a radon flux rate ranging from 0.45 to 75 $pCi \cdot m^{-2} \cdot sec^{-1}$.

Of 25 radon flux canisters placed within the large anomalous area at locations with non-anomalous gamma activity, one canister (H.03.09, 16.08.26) showed a radon flux rate of 1.75 $pCi \cdot m^{-2} \cdot sec^{-1}$ and may indicate the presence of buried source material not observed by surface gamma activity. Results from 40 boundary radon flux canisters placed around the anomalous areas were all less than 0.4 $pCi \cdot m^{-2} \cdot sec^{-1}$.

Radon flux rate results from the anomalous area G.00.15, 14.07.15 (soil sample NAI2049) were all less than 0.6 $pCi \cdot m^{-2} \cdot sec^{-1}$. Test results from a concrete sump with elevated gamma activity (N.03.10, 19.02.20; soil sample NAI2058) were all less than 0.15 $pCi \cdot m^{-2} \cdot sec^{-1}$. Forty-nine radon flux canisters were placed in 12 different subgrid locations and none of the radon flux rates exceeded 0.35 $pCi \cdot m^{-2} \cdot sec^{-1}$.

5.3.3 IR-03

No anomalous locations were found during the walkover gamma survey, therefore no radon flux canisters were placed.

5.3.4 IR-07

The five radon flux canisters placed in and around an anomaly (M.06.00, 3.01.15; soil sample NAI2124) in the paved parking area had a radon flux rate less than 0.3 $pCi \cdot m^{-2} \cdot sec^{-1}$.

5.3.5 IR-14

The ten radon flux canisters placed in 2 subgrid locations (N.03.00, 18.01.00 and N.09.00, 18.04.00) exhibited a radon flux rate less than 0.35 $pCi \cdot m^{-2} \cdot sec^{-1}$.

5.3.6 IR-15

No radon flux canisters were placed in IR-15 as no anomalous gamma activity was reported.

5.3.7 PA-18

No radon flux canisters were placed in PA-18 as no anomalous gamma activity was found.

5.3.8 PA-19

No radon flux canisters were placed in PA-19 as no anomalous gamma activity was found.

5.4 SUMMARY OF RADIOACTIVE MATERIAL CONCENTRATION IN SOILS AT HPA COMPARED TO EXPECTED BACKGROUND CONCENTRATIONS AND RESULTS OF SOIL GAMMA SPECTROSCOPY

The ^{226}Ra activity of the earth's crust averages about 0.7 pCi/g, while the average ^{226}Ra content of granitic rocks is about 1.4 pCi/g. Estimates of the ^{228}Ra activity in the earth's crust range from about 0.7 to 1.4 pCi/g. ^{226}Ra and ^{228}Ra are present in soils since they arise from the radioactive decay of naturally occurring uranium-238 (^{232}U) and thorium-232 (^{232}Th) respectively (Bropst and Pratt, 1973). ^{40}K is a primordial radionuclide which occurs naturally in soils at concentrations of 5 to 20 pCi/g. Estimates of the world average concentrations in soil of ^{226}Ra, ^{228}Ra, and ^{40}K are 0.8, 0.65, and 10 pCi/g respectively, as presented in National Council of Radiation Protection and Measurements (NCRP) Report No. 50 (1977b).

Neither ^{137}Cs nor ^{241}Am are naturally occurring radioactive materials. However, they are widely distributed in low concentrations on the earth's surface due to fallout from atmospheric testing of nuclear weapons. It has been estimated that the integrated deposit of ^{137}Cs from fallout averaged 12.8 pCi per square centimeter in the temperate latitudes of the northern hemisphere as of 1971 (UNSCEAR, 1972). Small amounts of ^{241}Am are present on the earth's surface as a result of beta decay of plutonium-241 (^{241}Pu) which was present in small amounts in nuclear weapons. The results of soil gamma spectroscopy and radiochemical analyses confirm that most soils at HPA have typical background levels of ^{226}Ra, ^{228}Ra, and ^{40}K. The point sources found in areas of HPA were found to contain ^{226}Ra and associated decay products. The point sources found were either ^{226}Ra-containing materials or chips of slag derived from ^{226}Ra-containing material. In a few cases, no discrete point source could be identified as the source of a radiation anomaly. It is estimated that a typical, ^{226}Ra-containing, intact radioluminescent source contains roughly one microCurie (μCi) of ^{226}Ra. This activity is equivalent to 1,000,000 pCi of ^{226}Ra.

If these ^{226}Ra-containing materials, assumed to contain one μCi ^{226}Ra, are distributed at a density of one radioluminescent source per cubic meter (m^3) of soil, this corresponds to an average ^{226}Ra concentration of about 1 pCi/g. The Uranium Mill Tailings Radiation Control Act (UMTRCA) soil concentration criteria for ^{226}Ra are found in 40 CFR 192 (EPA, 1978). These standards allow residual ^{226}Ra soil contamination levels of 5 pCi/g averaged over the upper 15 cm of soil in a 100 m^2 area. Although the UMTRCA soil criteria do not apply to radioluminescent ^{226}Ra materials, using this manner of comparison implies that the overall ^{226}Ra soil concentration in anomalous areas is not unduly high.

Although this calculated average soil concentration is not above 5 pCi/g, it, nonetheless, is undesirable to have concentrated point source radioluminescent material present at or within a few inches of the surface. Direct contact with the radioactive materials could result, particularly if the ^{226}Ra-containing-materials are unearthed by individuals or disturbed in the course of construction. It should be noted that a fence was installed that restricts the entry of unauthorized persons into landfill areas and controls access to soils containing elevated concentrations of ^{226}Ra.

^{137}Cs was detected in a majority of both the HPA IR area soil samples and background soil samples. The highest ^{137}Cs result for a surface soil sample was no more than a fraction of a pCi/g. Surface soil samples were not observed to contain unusual levels of ^{137}Cs in comparison to background samples. The amount of ^{137}Cs that was present in soil samples could have been deposited directly from the atmosphere.

^{241}Am was reported in 2 of 137 soil samples analyzed by gamma spectroscopy. For the two soil samples with positive ^{241}Am results, the minimum detectable activity (MDA) was barely exceeded, and both of the soil samples had high concentrations of ^{226}Ra. High concentrations of one radioisotope in a sample can cause interferences with the determination of other isotopes by gamma spectroscopy. No definitive conclusions can be drawn about the presence of ^{241}Am in the two samples in question. Overall, gamma spectroscopy did not provide any convincing evidence of unusual concentrations of ^{241}Am.

A few of the soil samples analyzed for isotopic plutonium had results which exceeded the MDA. The highest ^{238}Pu and $^{239/240}$Pu results were 0.12 and 0.05 pCi/g, respectively. The ^{238}Pu, $^{239/240}$Pu values for the 15 HPA soil samples collected fall within the range of values typically observed for background surface soil samples in the United States (Burnham, 1992). Background samples collected on or near HPA were not analyzed for ^{238}Pu and $^{239/240}$Pu. Table 2 shows the results of gamma spectroscopic analysis of soil samples.

TABLE 2
SUMMARY OF SOIL GAMMA SPECTROSCOPY RESULTS
(pCi/g)

(Sheet 1 of 7)

SAMPLE	SAMPLE LOCATION	Am-241	STD DEV	Cs-137	STD DEV	K-40	STD DEV	Ra-226	STD DEV	Ra-228	STD DEV	Th-228	STD DEV	Pu-239/240	STD DEV	Pu-238	STD DEV	NOTE
NAI2001	BACKGROUND 1	<0.31		0.134	0.083	8.1	1.7	0.48	0.19	0.77	0.40	0.71	0.27					
NAI2002	BACKGROUND 2	<0.31		0.155	0.087	10.5	2.1	0.34	0.18	1.05	0.52	0.66	0.37					
NAI2003	BACKGROUND 3	<0.12		0.229	0.064	4.82	0.87	0.62	0.13	1.25	0.31	0.99	0.20					
NAI2004	BACKGROUND 4	<0.41		0.38	0.15	12.0	2.4	1.05	0.27	1.51	0.55	1.36	0.42					
NAI2005	BACKGROUND 5	<0.23		<0.073		1.5	1.4	<0.11		<0.29		<0.21						
NAI2006	BACKGROUND 6	<0.30		<0.075		20.1	2.4	0.50	0.16	0.71	0.39	0.65	0.30					
NAI2007	BACKGROUND 7	<0.33		0.109	0.076	9.7	1.9	0.88	0.22	0.62	0.38	0.74	0.42					
NAI2008	BACKGROUND 8	<0.39		<0.079		14.0	2.2	1.13	0.25	1.44	0.46	1.36	0.47					
NAI2009	H.00.06, 16.01.24	<0.17		<0.091		8.7	18	4.36	0.29	0.74	0.31	0.86	0.32					1
NAI2010	H.01.00, 16.04.05	<0.13		0.17	0.13	12.5	1.4	0.87	0.17	0.57	0.30	0.74	0.20					1
NAI2011	H.01.09, 16.04.15	<1.5		<0.53		<6.5		611.6	2.8	<2.3		<1.7		<0.009		<0.01		1
NAI2012	H.02.14, 16.07.18	<0.32		<0.082		10.7	1.3	0.86	0.18	0.71	0.36	0.52	0.23					1
NAI2013	H.03.16, 16.05.12	<0.14		<0.063		7.8	1.4	1.22	0.20	0.76	0.34	0.61	0.22					1
NAI2014	H.03.09, 16.00.03	<1.9		<0.57		8.5	5.6	663.8	2.9	<2.3		<1.8		0.034	0.022	<0.018		2
NAI2015	G.09.15, 16.06.28	<0.11		0.051	0.073	11.3	1.2	0.55	0.11	0.76	0.29	0.55	0.18					1
NAI2016	G.07.17, 16.03.10	<7.8		<3.8		<43		1850.0	16	<14		<11						2
NAI2017	G.07.12, 16.00.29	<3.9		<1.5		<16		3905.0	7.2	<5.7		<4.4						2
NAI2018	G.06.18, 16.02.09	<0.48		0.99	0.274	7.4	2.3	53.01	0.79	<0.67		<0.49		0.042	0.002	<0.013		2
NAI2019	G.04.09, 16.02.18	<0.12		0.061	0.061	13.1	1.3	0.63	0.11	0.77	0.27	0.76	0.22					1
NAI2020	G.01.27, 16.03.12	<1.2		<0.059		15.2	1.3	0.58	0.14	0.59	0.28	0.57	0.19					1
NAI2021	G.04.01, 16.00.05	<0.36		<0.12		20.0	2.3	25.98	0.56	<0.52		<0.39						1

TABLE 2
SUMMARY OF SOIL GAMMA SPECTROSCOPY RESULTS
(pCi/g)

(Sheet 2 of 7)

SAMPLE	SAMPLE LOCATION	Am-241	STD DEV	Cs-137	STD DEV	K-40	STD DEV	Ra-226	STD DEV	Ra-228	STD DEV	Th-228	STD DEV	Pu-239/240	STD DEV	Pu-238	STD DEV	NOTE
NAI2022	G.01.17, 15.09.03	<0.52		<0.18		16.6	2.9	54.05	0.79	<0.72		<0.60		<0.015		<0.009		1
NAI2023	G.04.14, 15.06.07	<1.2		<0.37		8.0	4.1	348.3	2.1	<1.6		<1.2						2
NAI2024	G.06.20, 15.05.15	2.6	2.2	<0.83		<9.5		1523.0	4.4	<3.4		<2.6						2
NAI2025	G.07.02, 15.07.06	<0.37		0.11	0.12	19.6	2.0	19.59	0.51	<0.45		0.63	0.33					2
NAI2026	G.04.20, 15.08.05	<2.0		<0.52		<6.3		900	10	<2.3		<1.7						2
NAI2027	G.06.18, 16.00.20	<1.5		0.28	0.42	10.7	5.8	460	10	<1.9		<1.3						2
NAI2028	G.07.24, 16.02.18	<0.16		0.035	0.084	9.5	1.5	1.69	0.19	0.51	0.28	0.72	0.28					1
NAI2029	H.02.00, 15.07.00	<0.28		<0.065		13.0	1.6	0.45	0.17	0.60	0.34	0.47	0.24					3
NAI2030	G.03.00, 15.06.00	<0.31		0.319	0.078	18.0	1.9	0.38	0.14	0.72	0.36	0.48	0.30					3
NAI2031	G.03.28, 15.05.00	<0.29		<0.065		8.9	1.5	0.52	0.15	0.61	0.33	0.75	0.26					3
NAI2032	G.05.00, 15.05.00	<0.38		<0.097		11.7	2.1	0.47	0.25	0.25	0.40	0.27	0.31					3
NAI2033	G.06.00, 15.05.00	<0.09		<0.056		13.6	1.7	0.27	0.12	0.77	0.31	0.43	0.23					3
NAI2034	G.07.00, 15.05.00	<0.28		<0.063		14.2	1.7	0.52	0.16	0.75	0.30	0.43	0.22					3
NAI2035	G.08.20, 15.05.00	<0.30		<0.064		16.6	1.7	0.45	0.15	0.65	0.31	0.40	0.25					3
NAI2036	H.01.10, 15.05.00	<0.28		0.134	0.091	11.5	1.7	0.57	0.15	0.95	0.43	0.89	0.30					3
NAI2037	H.03.25, 15.05.00	<0.31		<0.058		24.7	1.9	0.26	0.15	0.40	0.31	0.58	0.30					3
NAI2038	H.05.00, 15.08.00	<0.28		<0.069		7.6	1.4	0.50	0.16	0.70	0.32	0.45	0.25					3
NAI2039	H.05.00, 16.00.00	<0.32		0.178	0.075	14.2	1.7	0.39	0.16	0.53	0.30	0.16	0.30					3
NAI2040	H.06.00, 16.02.00	<0.30		0.098	0.067	8.4	1.5	0.48	0.14	0.74	0.35	0.68	0.30					3
NAI2041	H.06.00, 16.03.00	<0.28		<0.067		9.9	1.4	0.56	0.16	0.43	0.27	0.37	0.27					3

TABLE 2
SUMMARY OF SOIL GAMMA SPECTROSCOPY RESULTS
(pCi/g)

(Sheet 3 of 7)

SAMPLE	SAMPLE LOCATION	Am-241	STD DEV	Cs-137	STD DEV	K-40	STD DEV	Ra-226	STD DEV	Ra-228	STD DEV	Th-228	STD DEV	Pu-239/240	STD DEV	Pu-238	STD DEV	NOTE
NAI2042	H.06.00, 16.05.00	<0.27		0.043	0.067	7.8	1.4	0.46	0.18	0.65	0.34	0.30	0.23					3
NAI2043	H.05.00, 16.06.00	<0.24		<0.059		12.0	1.4	0.45	0.15	0.48	0.29	0.54	0.23					3
NAI2044	H.05.00, 16.08.00	<0.27		0.130	0.084	10.9	1.6	0.39	0.18	0.58	0.27	0.39	0.23					3
NAI2045	N.04.00, 16.09.00	<0.31		<0.065		9.1	1.7	0.41	0.17	0.66	0.33	0.41	0.26					3
NAI2046	H.03.05, 17.00.00	<0.07		<0.067		6.0	1.3	0.34	0.17	0.47	0.33	0.35	0.23					3
NAI2047	H.02.00, 17.01.00	<0.07		<0.065		9.9	1.4	0.44	0.14	0.57	0.39	0.31	0.18					3
NAI2048	G.02.20, 14.01.05	<0.10		<0.071		13.9	1.6	0.58	0.18	0.82	0.29	0.74	0.26					4
NAI2049	G.00.15, 14.07.15	<0.09		0.11	0.13	11.0	1.7	2.01	0.24	0.56	0.33	0.48	0.22					4
NAI2050	G.00.12, 15.01.08	<0.11		0.09	0.13	9.9	1.8	0.93	0.24	1.59	0.44	1.5	0.38					4
NAI2051	I.02.15, 17.03.25	<0.11		0.044	0.073	14.5	1.9	1.26	0.24	0.45	0.39	0.50	0.29					4
NAI2052	F.09.20, 15.09.00	<0.31		<0.076		8.1	1.5	1.18	0.22	0.84	0.47	0.13	0.28	<0.016		<0.010		1
NAI2053	G.01.28, 16.03.28	<0.26		<0.062		9.1	1.4	0.27	0.15	0.68	0.39	0.36	0.23	<0.010		<0.022		1
NAI2054	G.05.03, 16.06.12	<0.30		<0.072		6.5	1.7	0.23	0.15	<0.34		0.23	0.27					1
NAI2055	E.04.16, 08.08.22	<0.16		<0.11		11.6	1.4	0.76	0.16	1.40	0.31	1.16	0.24	<0.017		<0.027		4
NAI2056	G.09.00, 11.03.15	<0.13		<0.10		8.5	1.2	0.60	0.12	0.73	0.27	0.69	0.22					4
NAI2057	K.05.28, 17.07.28	<0.12		0.192	0.077	11.9	1.2	0.45	0.11	0.57	0.26	0.47	0.17					4
NAI2058	N.03.10, 19.02.20	<0.14		0.40	0.10	19.2	1.6	0.42	0.14	0.52	0.28	0.51	0.19	0.045	0.032	<0.032		4
NAI2059	C.09.17, 11.06.28	<0.12		0.074	0.071	10.11	1.3	0.43	0.12	0.39	0.21	0.44	0.17					8
NAI2060	H.00.00, 10.01.00	<0.14		<0.12		10.3	1.5	0.52	0.16	0.89	0.35	1.05	0.23					5
NAI2061	A.08.00, 13.05.00	<0.12		<0.099		5.7	1.0	0.54	0.12	0.82	0.22	0.68	0.24					5
NAI2062	A.08.00, 14.00.00	<0.14		<0.10		8.5	1.2	0.53	0.16	0.69	0.26	0.80	0.14					5
NAI2063	B.02.00, 14.01.00	<0.14		0.20	0.10	8.6	1.2	0.68	0.13	0.72	0.31	0.62	0.23					5

TABLE 2
SUMMARY OF SOIL GAMMA SPECTROSCOPY RESULTS
(pCi/g)

(Sheet 4 of 7)

SAMPLE	SAMPLE LOCATION	Am-241	STD DEV	Cs-137	STD DEV	K-40	STD DEV	Ra-226	STD DEV	Ra-228	STD DEV	Th-228	STD DEV	Pu-239/240	STD DEV	Pu-238	STD DEV	NOTE
NAI2064	B.00.00, 13.02.00	<0.16		<0.12		9.9	1.4	0.76	0.17	0.78	0.34	1.04	0.27	<0.017		0.033	0.011	5
NAI2065	C.08.00, 11.02.00	<0.14		0.114	0.081	7.9	1.2	0.49	0.14	0.78	0.30	0.66	0.21					5
NAI2066	E.01.00, 11.02.00	<0.11		<0.11		19.5	1.6	0.14	0.11	0.35	0.18	0.36	0.18					5
NAI2067	E.03.00, 10.08.00	<0.13		<0.12		10.2	1.5	0.48	0.15	0.62	0.26	0.67	0.23					5
NAI2068	E.04.00, 09.09.00	<0.14		0.040	0.088	17.7	1.5	0.64	0.15	1.02	0.34	0.87	0.23					5
NAI2069	F.06.00, 09.09.00	<0.12		0.13	0.10	5.1	1.3	0.34	0.17	0.42	0.31	0.48	0.22					5
NAI2071	F.07.00, 11.04.00	<0.09		<0.096		<1.2		<0.08		<0.18		<0.12						5
NAI2072	F.09.00, 1302.00	<0.17		<0.16		10.3	1.8	0.52	0.17	0.33	0.30	0.25	0.22					5
NAI2073	G.09.00, 14.03.00	<0.14		0.049	0.067	8.8	1.2	0.58	0.11	0.83	0.27	0.74	0.20					5
NAI2074	G.05.00, 15.03.00	<0.10		<0.050		12.4	1.3	0.23	0.11	0.39	0.26	0.31	0.19					5
NAI2075	G.09.00, 14.03.00	<0.12		0.058	0.058	20.5	1.5	0.34	0.13	0.36	0.31	0.39	0.15					5
NAI2076	H.04.12, 16.03.00	<0.10		0.049	0.043	5.6	1.1	<0.11		0.18	0.21	0.16	0.15					5
NAI2077	G.06.00, 16.07.20	<0.13		0.171	0.086	13.6	1.4	0.46	0.15	0.59	0.28	0.44	0.20					5
NAI2078	H.01.00, 17.02.00	<0.10		0.026	0.043	7.9	1.2	<0.12		<0.23		0.23	0.15					5
NAI2080	B.09.00, 12.06.00	<0.20		<0.084		21.8	2.2	0.36	0.18	0.85	0.45	0.64	0.32					5
NAI2081	D.05.00, 11.05.00	<0.16		<0.080		8.6	1.5	0.55	0.20	0.35	0.36	0.64	0.37					5
NAI2082	D.04.00, 10.05.00	<0.19		<0.069		12.4	1.7	0.59	0.24	1.31	0.40	0.89	0.32					5
NAI2083	F.03.00, 12.02.00	<0.16		0.087	0.096	1.6	1.5	0.25	0.16	1.42	0.68	0.47	0.37					5
NAI2084	G.06.00, 11.05.00	<0.16		<0.075		8.0	1.4	0.46	0.17	0.98	0.50	0.51	0.24					5
NAI2085	I.03.00, 16.05.00	<0.16		0.168	0.099	9.5	2.0	0.59	0.20	0.82	0.48	0.54	0.36					5
NAI2086	I.00.00, 17.05.00	<0.15		0.040	0.079	6.1	1.5	0.48	0.16	0.53	0.33	0.58	0.21	<0.016		<0.016		5

TABLE 2
SUMMARY OF SOIL GAMMA SPECTROSCOPY RESULTS
(pCi/g)

(Sheet 5 of 7)

SAMPLE	SAMPLE LOCATION	Am-241	STD DEV	Cs-137	STD DEV	K-40	STD DEV	Ra-226	STD DEV	Ra-228	STD DEV	Th-228	STD DEV	Pu-239/240	STD DEV	Pu-238	STD DEV	NOTE
NAI2087	J.01.00, 16.01.00	<0.17		<0.089		10.0	1.6	0.30	0.16	0.55	0.39	0.50	0.28					5
NAI2088	I.07.00, 15.06.00	<0.16		0.21	0.10	9.7	1.6	0.49	0.19	0.49	0.32	0.44	0.23	0.44	0.23			5
NAI2089	K.06.00, 18.01.00	<0.11		<0.059		9.4	1.3	0.52	0.15	0.65	0.28	0.37	0.24					5
NAI2090	L.03.00, 18.02.00	<0.39		<0.098		15.2	2.3	0.68	0.28	0.40	0.52	0.63	0.37					5
NAI2091	M.02.00, 18.05.00	<0.41		0.16	0.14	14.8	2.5	0.47	0.21	0.51	0.50	0.54	0.40					5
NAI2092	M.04.00, 19.04.00	<0.28		<0.058		19.3	1.8	0.59	0.22	0.43	0.37	0.56	0.28	<0.009		<0.009		5
NAI2093	I.06.00, 19.03.00	<0.28		<0.061		6.1	1.4	1.14	0.19	0.32	0.29	0.35	0.25					5
NAI2094	N.00.00, 19.04.08	<0.28		<0.067		21.3	2.0	0.38	0.17	0.44	0.35	0.57	0.29					5
NAI2095	N.04.00, 19.05.00	<0.48		<0.047		1.2	1.1	<0.12		0.16	0.24	<0.21						5
NAI2096	O.01.00, 18.04.00	<0.29		<0.068		6.8	1.4	1.10	0.18	0.53	0.45	0.65	0.36	<0.008		<0.008		5
NAI2097	O.05.00, 19.01.00	<0.24		<0.068		11.8	1.6	0.33	0.15	0.24	0.32	0.37	0.21					5
NAI2098	Q.05.00, 20.06.00	<0.28		0.376	0.089	9.3	1.5	0.39	0.14	0.37	0.28	0.44	0.28					5
NAI2100	F.03.00, 10.09.00	<0.13		<0.065		8.9	1.3	0.72	0.14	1.25	0.34	1.00	0.23					5
NAI2101	F.06.00, 14.07.00	<0.10		<0.053		8.2	1.0	0.27	0.12	0.26	0.25	<0.17						5
NAI2102	F.04.00, 15.04.00	<0.09		0.082	0.059	5.4	0.94	0.26	0.14	0.52	0.22	0.30	0.15					5
NAI2103	K.01.28, 17.02.00	<0.13		<0.058		20.9	1.5	0.58	0.15	0.76	0.36	0.55	0.22					5
NAI2104	J.03.28, 17.05.27	<0.13		<0.067		23.5	1.7	0.68	0.17	0.59	0.40	0.74	0.28	<0.015		<0.023		5
NAI2106	P.09.00, 21.02.00	<0.12		0.051	0.073	9.1	1.1	0.57	0.15	0.67	0.29	0.58	0.19					5
NAI2107	M.08.00, 02.06.00	<0.11		<0.053		10.1	1.1	0.22	0.09	0.35	0.21	0.20	0.13	<0.014		0.028	0.022	5
NAI2108	M.04.00, 03.05.00	<0.08		<0.044		<1.0		<0.01		<0.18		<0.16						5
NAI2109	L.03.00, 03.03.00	<0.08		<0.044		1.70	0.72	<0.09		0.17	0.18	<0.14						5

TABLE 2
SUMMARY OF SOIL GAMMA SPECTROSCOPY RESULTS
(pCi/g)

(Sheet 6 of 7)

SAMPLE	SAMPLE LOCATION	Am-241	STD DEV	Cs-137	STD DEV	K-40	STD DEV	Ra-226	STD DEV	Ra-228	STD DEV	Th-228	STD DEV	Pu-239/240	STD DEV	Pu-238	STD DEV	NOTE
NAI2110	L.02.00, 04.03.00	<0.08		<0.047		<1.0		<0.08		<0.17		<0.12						5
NAI2111	M.00.00, 04.08.00	<0.13		<0.053		3.56	0.82	1.30	0.15	1.89	0.36	1.95	0.24					5
NAI2112	Q.00.00, 21.03.25	<0.26		0.055	0.074	9.2	1.5	0.47	0.17	0.46	0.35	0.45	0.22					5
NAI2113	Q.05.20, 20.04.25	<0.27		<0.07		11.8	1.6	0.41	0.12	0.64	0.37	0.55	0.23					5
NAI2115	A.05.12, 14.00.08	<0.31		<0.069		8.5	1.4	0.57	0.18	1.10	0.42	0.90	0.31	<0.016		0.034	0.026	4
NAI2116	A.09.06, 13.07.25	<0.34		0.071	0.064	8.9	1.5	0.90	0.18	1.55	0.38	1.28	0.31	<0.015		0.117	0.046	4
NAI2117	B.00.25, 13.04.18	<0.15		0.107	0.063	9.0	1.3	0.51	0.16	0.73	0.28	0.82	0.28	<0.014		0.051	0.034	4
NAI2118	B.05.05, 13.01.25	<2.9		<47		14.5	7.9	454.6	2.9	<2.5		<1.6						8
NAI2120	N.05.25, 03.00.08	<0.20		0.11	0.11	34.5	2.4	0.87	0.22	1.08	0.42	0.90	0.25					7
NAI2121	N.08.00, 02.06.00	<0.14		0.035	0.076	21.4	1.7	0.26	0.12	0.58	0.36	0.39	0.16					7
NAI2122	M.01.10, 04.06.10	<0.19		<0.11		9.0	1.3	1.53	0.20	1.54	0.43	1.79	0.32					4
NAI2124	M.06.00, 03.01.15	<0.19		<0.088		9.2	1.3	1.37	0.19	1.99	0.44	1.89	0.27					4
NAI2125	M.08.10, 04.00.15	<0.22		0.186	0.075	10.2	1.5	5.24	0.28	1.27	0.44	1.04	0.27					4
NAI2127	O.02.22, 18.04.12	<0.25		<0.065		7.0	1.2	0.91	0.16	2.19	0.43	1.61	0.27					4
NAI2128	L.06.15, 18.06.12	<0.27		<0.068		10.7	1.5	2.00	0.23	1.80	0.41	1.47	0.27					4
NAI2129	L.09.05, 18.08.07	<0.28		<0.076		8.7	1.4	1.34	0.21	1.94	0.44	1.97	0.38					4
NAI2130	L.04.27, 04.08.29	<0.28		<0.076		7.8	1.5	1.34	0.21	1.94	0.44	1.97	0.38					4
NAI2131	BUILDING 901 PLANTER	<0.21		<0.076		16.1	1.8	0.56	0.17	0.62	0.38	0.56	0.21					6
NAI2133	DRY DOCK 4 SUMP	<78		<11		110	197	<23		56	69	<35						
NAI2134	H.06.00, 17.03.00	<0.17		<0.071		25.4	1.7	0.95	0.18	1.34	0.35	1.27	0.30					3
NAI2135	H.04.00, 17.07.00	<0.10		<0.053		2.33	0.86	0.32	0.12	0.54	0.35	0.22	0.17					3

TABLE 2
SUMMARY OF SOIL GAMMA SPECTROSCOPY RESULTS
(pCi/g)

(Sheet 7 of 7)

SAMPLE	SAMPLE LOCATION	Am-241	STD DEV	Cs-137	STD DEV	K-40	STD DEV	Ra-226	STD DEV	Ra-228	STD DEV	Th-228	STD DEV	Pu-239/240	STD DEV	Pu-238	STD DEV	NOTE
NAI2136	Q.06.24, 21.00.20	1.1	1.3	<0.42		12.9	5.4	412.1	2.2	<1.7		<11						4
NAI2137	Q.07.20, 21.00.10	<0.43		<0.13		19.2	2.2	39.69	0.65	0.63	0.55	0.63	0.55					4

Notes:

1 Anomaly located in large area H.00.00, 16.00.00 with visible source material removed from sample
2 Anomaly located in large area H.00.00, 16.00.00 with visible source material not removed from sample
3 Boundary sample for large area H.00.00, 16.00.00
4 Other anomalous location
5 Systematic samples
6 PA-19 planter sample
7 Beach sand
8 No radioactive material was removed from sample prior to analysis

5.4.1 IR-01

^{226}Ra-containing-material was removed from location C.09.17, 11.06.28 and the soil analysis reported 0.43 pCi/g ^{226}Ra. An anomalous location with no visible radioactive source material was sampled at B.05.05, 13.01.25 and the soil sample reported 454.6 pCi/g ^{226}Ra.

Boreholes located near the northwest property corner had gamma activity greater than 50 percent above the general area and were investigated with the placement of radon flux canisters and soil sampling. Later, it was determined that by surrounding the detector with soils inside the borehole, detector geometry had influenced the readings. One soil sample was collected from subgrid location E.04.16, 08.08.22 that was analyzed and determined to contain 0.76 pCi/g ^{226}Ra.

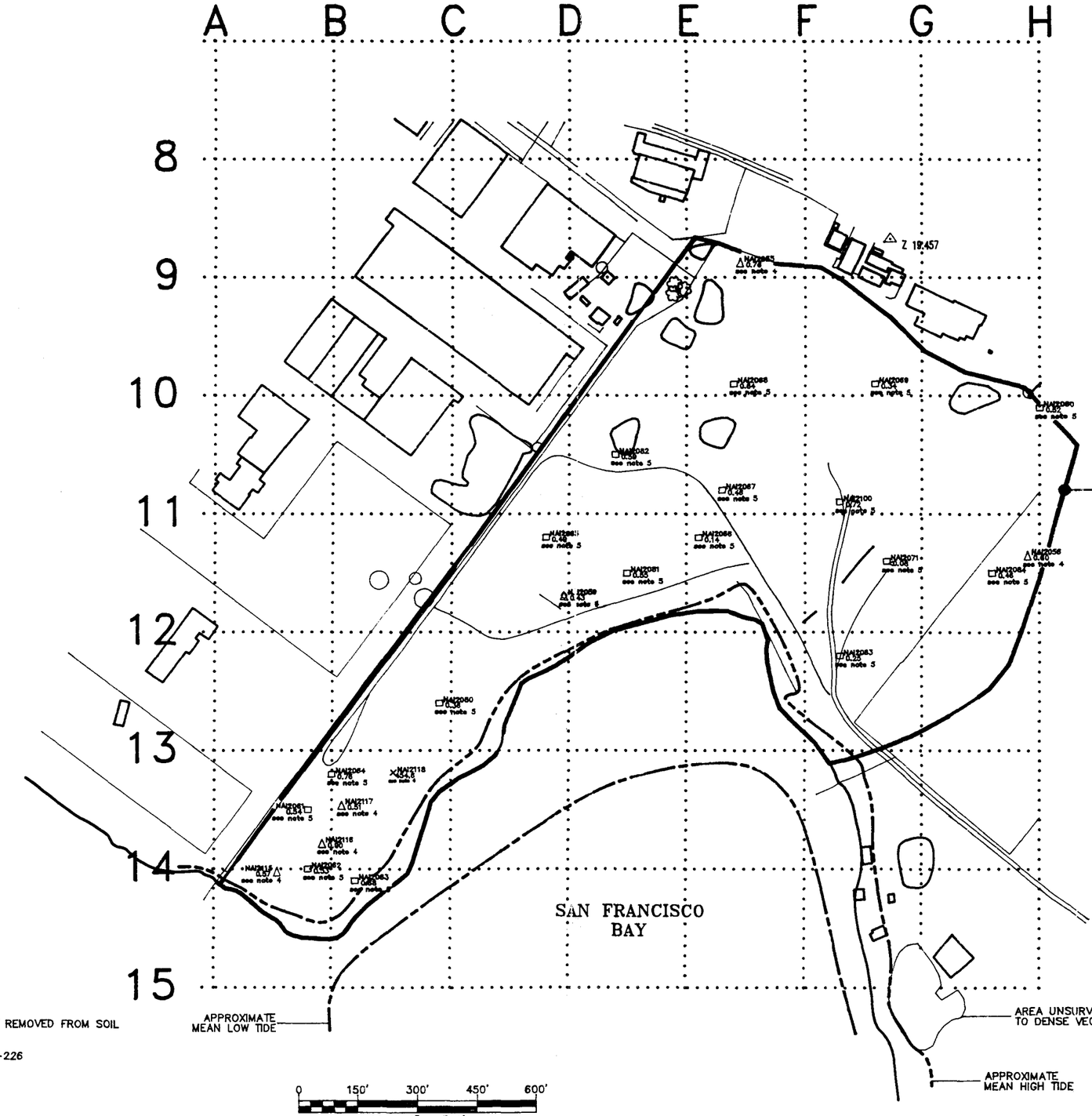
Anomaly investigations at the boreholes in the northwest corner of IR-01 reported 0.76 pCi/g ^{226}Ra and an investigation of anomalous gamma activity near granite stone curbing reported 0.60 pCi/g ^{226}Ra. Three samples collected from sands with anomalous gamma activity ranged from 0.51 to 0.90 pCi/g ^{226}Ra. Analysis of ^{226}Ra concentration in 19 soil samples ranged from 0.14 to 0.72 pCi/g ^{226}Ra. A total of 26 soil samples was collected from IR-01. Two of these samples had identifiable and visible source material that was removed before being sent to the laboratory for analysis. Figure 16 shows the location of soil sample collection at IR-01.

5.4.2 IR-02

Within the large area anomaly located around grid H.00.00, 16.00.00, 20 samples (NAI2009 through NAI2028) reported ^{226}Ra concentrations from 0.23 to 11,850 pCi/g. ^{226}Ra-containing materials or metal source materials were removed from the area at ten sampling locations prior to soil sample collection. Laboratory results indicated that ^{226}Ra concentrations were elevated in these samples, ranging from 1.69 to 612 pCi/g, which suggests that radioactivity still remained in the soil matrix after the source was removed. This is significant because it suggests that the migration of ^{226}Ra from the source to the soil occurred at this location.

Ten other samples were collected in matrices containing slag and metal objects that appeared to have been formed together in a crucible or furnace. Weathering allowed some of the matrix to spread into the surrounding soil. The activities of these samples ranged from 19.59 to 11,850 pCi/g ^{226}Ra, and one sample reported 2.6 pCi/g ^{241}Am.

Additional gamma measurements taken during sampling activities while excavating the sources indicated the presence of anomalous material remaining after sample collection. Three soil



NOTES:

4. Other anomalous location
5. Systematic soil sample

LEGEND

- ○ RADIOACTIVE POINT SOURCE ANOMALY / REMOVED FROM SOIL
- □ SYSTEMATIC SOIL SAMPLE <5pCi/gm Ra–226
- △ SOIL SAMPLE <5pCi/gm Ra–226
- × SOIL SAMPLE >5pCi/gm Ra–226

FIGURE 16
LOCATION OF SOIL SAMPLE COLLECTION AT IR–01
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

samples (NAI2052, NAI2053, and NAI2054) collected on the shoreline ranged in concentration from 0.23 to 1.18 pCi/g ^{226}Ra. The discrete sources were removed prior to sample collection. Twenty-one anomalous area boundary samples (NAI2029 through NAI2047, NAI2134, and NAI2135) taken to the north and east of the large area ranged from 0.1 to 0.95 pCi/g ^{226}Ra.

^{226}Ra-containing material was removed from grid location G.00.12, 15.01.18 and one from grid location I.02.15, 17.03.25. ^{226}Ra concentrations at these locations were 2.01 and 1.26 pCi/g in the soil, respectively. Two grid locations G.02.20, 14.01.15 and G.00.12, 15.01.08, where soil sampling produced no identifiable sources, reported ^{226}Ra concentrations of 0.58 and 0.93 pCi/g, respectively.

The sample taken beside a large rock surrounded with solidified melted slag at grid location K.05.28, 17.07.28 reported a ^{226}Ra concentration of 0.45 pCi/g, suggesting that the contaminated material had not become dispersed into the soil. The sample taken inside the concrete lined sump at grid location N.03.10, 19.02.20 reported ^{226}Ra concentrations of 0.42 pCi/g. In addition, samples collected immediately north of IR-03 (Oil Reclamation Area) reported ^{226}Ra concentrations ranging from 1.34 to 2.00 pCi/g.

Two samples collected at anomalies near Berths 30 and 35 at grid locations Q.06.24, 21.00.20 and Q.07.20, 21.00.20 reported ^{226}Ra concentrations of 412.1 and 39.69 pCi/g, respectively. The sample matrix was gravel/soil with no ^{226}Ra-containing materials evident.

A total of 79 soil samples were collected from IR-02. Twenty-five of these samples had identifiable and visible source material that was removed before they were sent to the laboratory for analysis. Figure 17 shows the location of soil sample collection at IR-02, IR-03, IR-14, and IR-15. Figure 18 shows the location of soil sample collection surrounding grid coordinate H.00.00, 16.00.00 at IR-02.

Analysis of 25 systematic soil samples in IR-02 ranged from 0.15 to 1.14 pCi/g ^{226}Ra.

5.4.3 IR-03

No anomalous areas were noted in the surface walkover gamma survey, and no samples were collected.

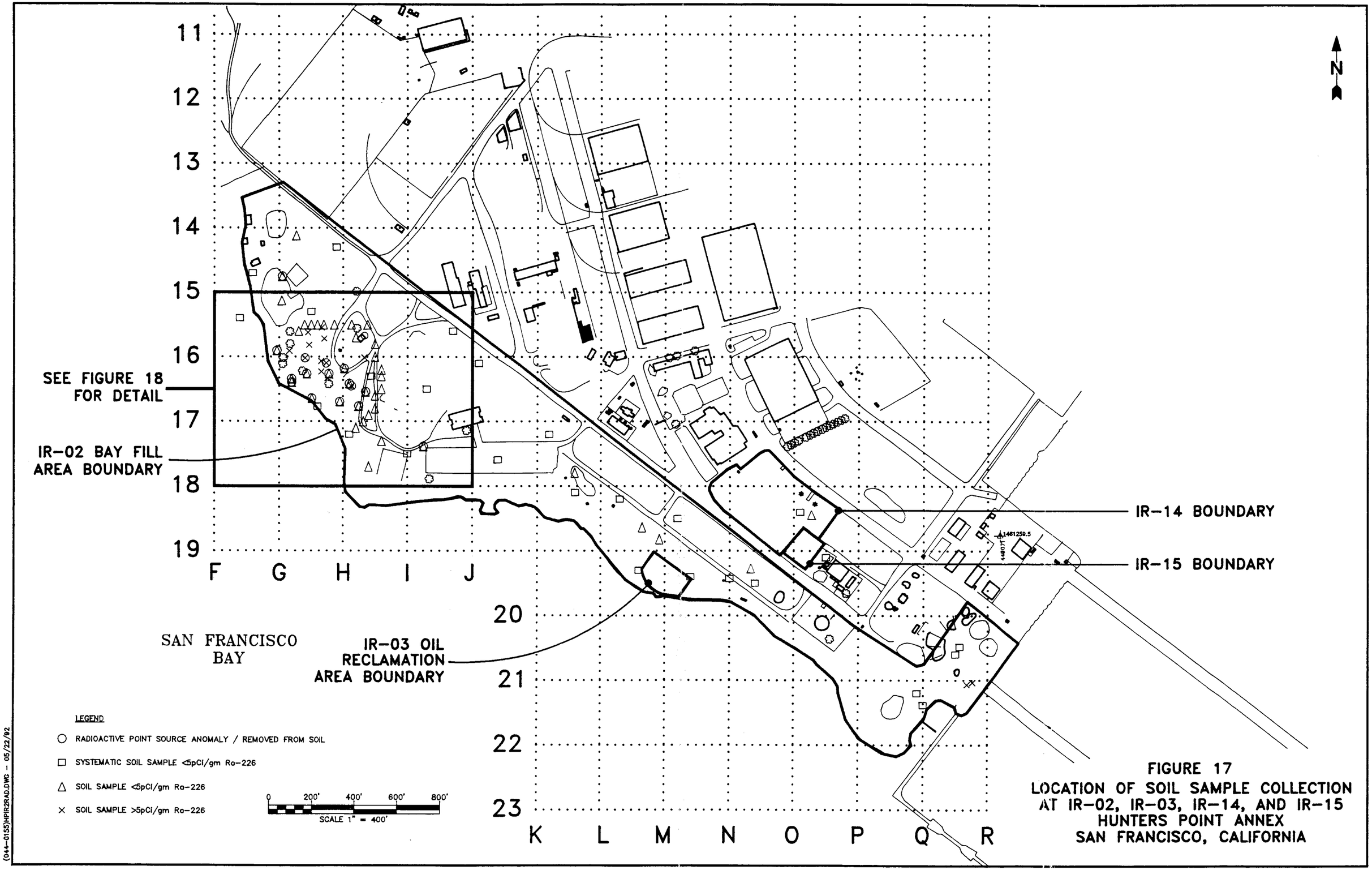


FIGURE 17
LOCATION OF SOIL SAMPLE COLLECTION
AT IR-02, IR-03, IR-14, AND IR-15
HUNTERS POINT ANNEX
SAN FRANCISCO, CALIFORNIA

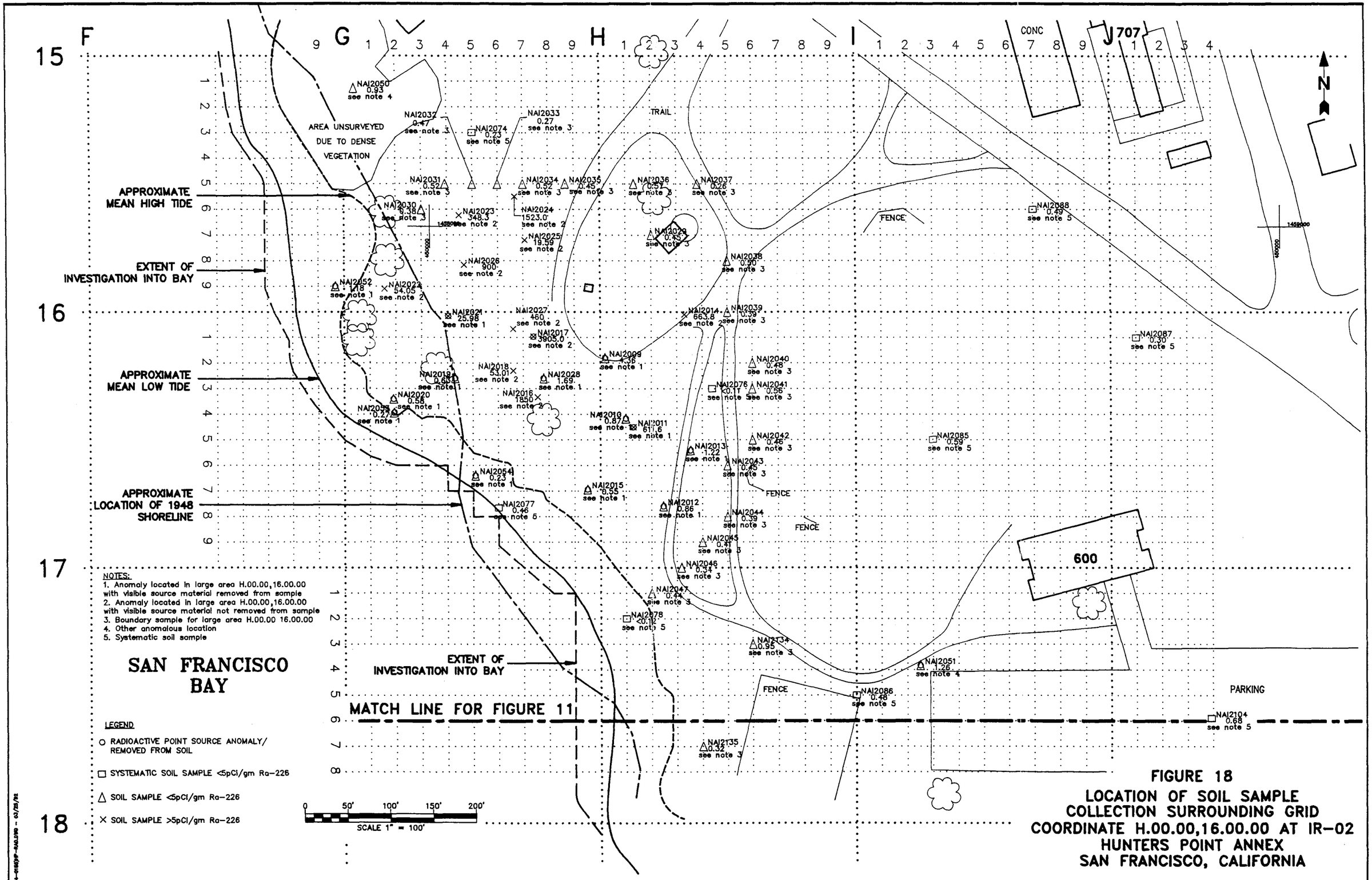


FIGURE 18
LOCATION OF SOIL SAMPLE COLLECTION SURROUNDING GRID COORDINATE H.00.00,16.00.00 AT IR-02 HUNTERS POINT ANNEX SAN FRANCISCO, CALIFORNIA

5.4.4 IR-07

Analysis of an anomaly in the parking lot reported a ^{226}Ra concentration of 1.37 pCi/g. Laboratory analysis of a sample collected at grid location M.08.10, 4.00.05 near the boundary with Donahue street reported a ^{226}Ra concentration of 5.24 pCi/g. Other samples ranged in concentrations of ^{226}Ra from <0.01 to 0.87 pCi/g. A total of seven soil samples was collected from IR-07. None of these samples had identifiable and visible source material that was removed before being sent to the laboratory for analysis. Figure 19 shows the location of soil sample collection at IR-07.

5.4.5 IR-14

One soil sample (NAI2127) was collected from sands at a suspected anomaly. The ^{226}Ra concentration of that sample was 0.91 pCi/g. Two systematic samples were also collected.

Three soil samples were collected from IR-14. None of these samples had identifiable and visible source material that was removed before they were sent to the laboratory for analysis. Figure 17 shows the location of soil sample collection at IR-14.

5.4.6 IR-15

No anomalous areas were noted in the surface walkover gamma survey, and no samples were collected.

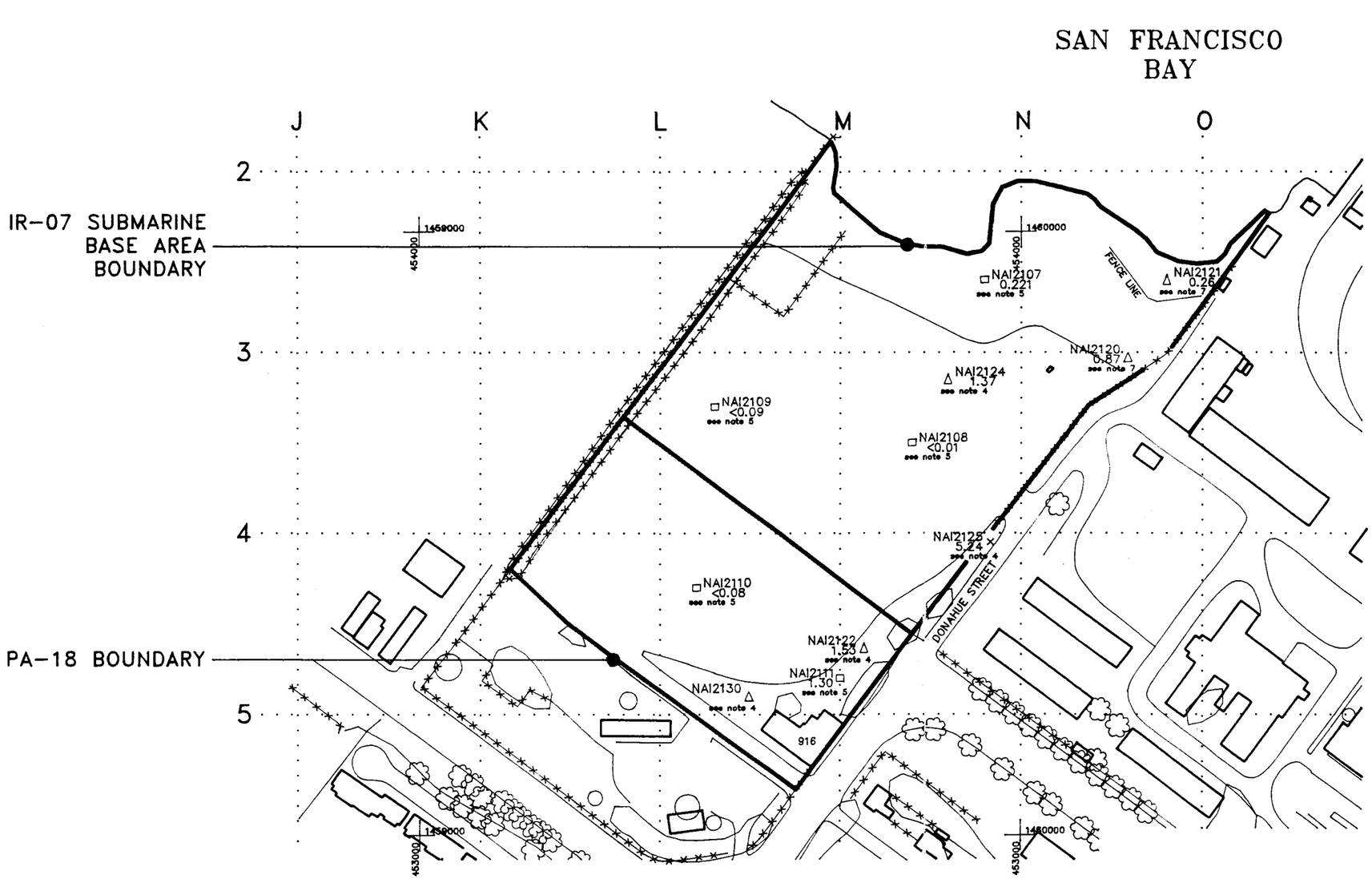
5.4.7 PA-18

Two samples (NAI2122 and NAI2130) collected at anomalous locations reported ^{226}Ra concentrations at 1.3 and 1.5 pCi/g, respectively. Two systematic samples (NAI2110 and NAI2111) reported ^{226}Ra concentrations of <0.08 and 1.3 pCi/g, respectively.

A total of 4 soil samples were collected from PA-18. None of these samples had identifiable and visible source material that was removed before they were sent to the laboratory for analysis. Figure 19 shows the location of soil sample collection at PA-18.

5.4.8 PA-19

No anomalous areas were reported during the surface gamma walkover survey. However, a systematic soil sample was collected at the planter, which reported a ^{226}Ra concentration of 0.56 pCi/g. This sample was obtained as a representative measure of the ^{226}Ra concentration in the soil.



LEGEND

- □ SYSTEMATIC SOIL SAMPLE <5pCi/gm Ra-226
- ○ RADIOACTIVE POINT SOURCE ANOMALY / REMOVED FROM SOIL
- △ SOIL SAMPLE <5pCi/gm Ra-226
- × SOIL SAMPLE >5pCi/gm Ra-226
- 916 BUILDING 916 - "DAGO MARY'S"

NOTES:

4. Anomalous location
5. Systematic soil sample
7. Beach sand

FIGURE 19
LOCATION OF SOIL SAMPLE COLLECTION AT IR-07 AND PA-18 HUNTERS POINT ANNEX SAN FRANCISCO, CALIFORNIA

(044-0155)\IR7RAD.DWG - 04/15/92

5.5 GROUNDWATER AND BAY WATER SAMPLE RESULTS

Nine groundwater samples and two Bay water samples were collected between February 7, 1992 and February 12, 1992. The results for each sample are discussed in the following sections. Table 3 shows the analytical results of each water sample. Nine groundwater samples were collected from selected monitoring wells over four IR sites. Bay water samples were collected from two tidal stations. The locations of the monitoring wells and the tidal stations are shown on Figure 4. The samples were submitted to a laboratory for gross alpha and beta analysis using EPA Method 900.0, commonly used for the evaluation of drinking water. It was previously known that elevated concentrations of dissolved solids in the water samples, causing self absorption of emitted alpha and beta particles, would affect the results of this particular analysis. Nonetheless, the analysis was performed to confirm the previous sampling [Phase 2] results for gross alpha and beta (HLA, 1991).

Since the Phase 2 test results for 175 groundwater samples using EPA Method 900.0 were not conclusive, only nine selected wells were resampled under the SCRS. Resampling and analysis of nine wells that had exhibited elevated gross alpha and beta activity was done to determine if analytical values were reproducible by another laboratory. If results were indeed reproducible, then an uncertainty factor could be applied to the results of all 175 groundwater samples previously analyzed for gross alpha and beta. This factor could be obtained by counting a laboratory spike sample and noting the variation of alpha and beta counts with changes in TDS concentrations.

Unfortunately, the water sample results did not provide sufficient valid information to confirm or refute the presence of radioactivity in the groundwater at HPA because the dissolved solids in the water samples were rather high. The high density solids required the laboratory to use a small aliquot size for the gross alpha and gross beta analyses. The inevitable consequences of small aliquot sizes for gross alpha/beta analyses result in (1) high standard deviations and (2) high detection limits. To address the beta contamination component and to define the contribution of beta emissions from ^{40}K, total potassium and ^{40}K were analyzed for. ^{40}K was estimated from the total potassium concentration present in each water sample, using atomic absorption spectroscopy. The relative concentration of ^{40}K in natural potassium is about 0.01 percent. Therefore an estimation of the ^{40}K present in total potassium was made for each water sample, and the concurrent beta activity determined. ^{40}K concentration is not of regulatory concern since it has no primary drinking water standard. If the gross beta activity could not be solely accounted for by beta decay of ^{40}K, then radiochemical analysis for strontium-90 (^{90}Sr) was performed. The beta radioactivity is essentially accounted for by contributions from ^{40}K, a naturally occurring isotope in salt water. Because beta activity could be accounted for by ^{40}K, radiochemical analyses for specific beta emitting isotopes

TABLE 3

SUMMARY OF GROUNDWATER AND BAY WATER RESULTS[1]

Sample No.	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	K-40 (pCi/L)	Other (pCi/L)
9206X499 IR09-MW38A	< 4.1	< 4.1	4.2	--
9206X503 IR10-MW13A2	< 30	< 18.7	10	Ra-226: 12 (16)[1]
9206X505 IR02-MW175A	< 75	<208	335	--
9206X506 IR02-MW179A	<275	<180	355	--
9206X507 FIELD BLANK	< 1.17	< 3.62	-8.5	--
9206X508 IR02-MWB2	<210	<544	400	Ra-226: 11 (15)
9206X509 IR02-MWB3	<219	<550	177	Ra-228: 25 (36)
9206X510 IR02-MWB1	<229	<531	242	--
9206X511 IR07-MWA1	<236	<469	358	--
9206X512 IR07-MWA1 DUP	<250	<575	377	Ra-228: 32 (40)
9206X513 EQUIP. BLANK	< 1.05	< 3.92	-0.3	--
9206X514 IR02-MW127B	< 48	<123	112	Ra-228: 39 (35)
9206X515 TIDAL STATION 1	<168	<117	15.2	Ra-228: <37 --
9206X516 TIDAL STATION 2	<194	<114	14.0	--

Note:

[1] The error term representing two standard deviations of the result is in parentheses. In cases where the result does not exceed the MDA, the value is reported as less than (<) the MDA value.

were not required (i.e., ^{90}Sr and ^{137}Cs) to determine if these isotopes were present in the water samples. Additionally, gamma spectroscopy employing a high purity germanium-lithium detector was used on the water samples to identify any possible gamma emitting contaminants that may have been present.

Gamma spectroscopy performed on water samples could not provide low enough detection limits for drinking water criteria and were not reliable enough to determine whether or not the ^{226}Ra was present in significant amounts. The average background ^{226}Ra concentration in California drinking water ranges from <0.18 to 1.06 pCi/L state-wide (Cothern and Reburs, 1990). The maximum contaminant levels (MCLs) for the combination of ^{226}Ra and ^{228}Ra in drinking water is 5 pCi/L. The original laboratory analytical plan was to evaporate the water samples to dryness and then analyze the dissolved solids by gamma spectroscopy.

To be practical, this procedure would have required a dissolved solid concentration of about 3 percent. This concentration of dissolved solids was not present in most of the water samples. Therefore, the water samples were analyzed by gamma spectroscopy as a water sample instead of as a dissolved solids sample. Consequently, the detection limit was increased to the point that evaluation of ^{226}Ra at levels less than 5 pCi/L was impractical. Analysis of water samples by radiochemical analysis would be required to determine if ^{226}Ra is present in water samples at concentrations of a few pCi/L.

The gross alpha, gross beta, ^{40}K, and gamma spectroscopy results obtained from the Bay water samples are essentially normal for seawater or brine samples. Radiochemical analysis was not required for any of the water samples to determine if less than 5 to 10 pCi/L of ^{137}Cs, ^{90}Sr, or are present but is required for ^{226}Ra.

5.5.1 IR-02 - Water Samples No. 9206X514 (IR-02 - MW127B), 9206X505 (IR-02 - MW175A), 9206X506 (IR-02 - MW179A), 9206X508 (IR-02 - MWB2), 9206X509 (IR-02 - MWB3), and 9206X510 (IR-02 - MWB1)

The amount of dissolved solids in these samples was elevated enough to seriously interfere with the gross alpha and gross beta analysis. The MDAs for gross alpha and beta results were far too high to conclude that the drinking water standard of 5 pCi/L for ^{226}Ra was not exceeded. The gross beta activity in these samples was accounted for by ^{40}K.

5.5.2 IR-07 - Water Samples No. 9206X511 (IR-07 - MW20A1) and 9206X512 (IR-07 - MW20A1 duplicate)

The amount of dissolved solids in these samples was elevated enough to very seriously interfere with the gross alpha and gross beta analyses. The MDAs for gross alpha and beta results were far too high to conclude that the drinking water standard of 5 pCi/L for ^{226}Ra was not exceeded. The gross beta activity in these samples was accounted for by ^{40}K.

5.5.3 IR-09 - Water Sample No. 9206X499 (IR-09 - MW38A)

The amount of dissolved solids in this sample was lower than the rest of the samples but the gross alpha and beta results are not low enough to conclude that the ^{226}Ra drinking water standard of 5 pCi/L was not exceeded. The gross beta activity in this sample was accounted for by ^{40}K.

5.5.4 IR-10 - Water Sample No. 9206X503 (IR-10 - MW13A2)

The amount of dissolved solids in this sample was elevated enough to interfere with the gross alpha and gross beta analysis. The MDA for gross alpha results were too high to conclude that the ^{226}Ra drinking water standard of 5 pCi/L was not exceeded. The gross beta activity in this sample was accounted for by ^{40}K.

5.5.5 Tidal Stations

The amount of dissolved solids in water samples No. 9206X515 and 9206X516 from two tidal stations was elevated enough to critically interfere with the gross alpha and gross beta analysis. The MDA for gross alpha and beta results were far too high to conclude that the ^{226}Ra drinking water standard of 5 pCi/L was not exceeded. Significant gross beta activity seen in these samples was determined to be due to ^{40}K.

5.5.6 Blanks

The amount of dissolved solids in the blank water sample No. 9206X507 and the equipment blank water sample No. 9206X513 was low. The gross alpha and beta results were low enough to conclude that the ^{226}Ra drinking water standard of 5 pCi/L was not exceeded.

5.6 DOWNHOLE GAMMA RADIATION SURVEY RESULTS

All of the nine groundwater wells surveyed, except one, exhibited a 150 to 200 percent increase above background surface gamma activity in the level of gamma activity between 2 and 6 feet below ground level. Only the groundwater well, MW127-B in IR-02, did not have an elevated count rate in this depth range.

An initial review of the monitoring well construction logs indicates that there is a general correlation between the increase in gamma activity and the location of the bentonite seal placed at the top of the sandpack at the time of well completion. This increase in gamma activity may be due to the presence of naturally occurring ^{40}K and ^{232}Th in the bentonite. Additional support for this explanation can be seen in the anomalous activity reported from the surface grouting in the sunken boreholes located at the northwest corner of IR-01. These boreholes have been filled with grout material that is a mixture of Portland cement and bentonite. Data collection sheets with results of downhole surveys are provided in Appendix B.

5.7 CURSORY SURVEY RESULTS

The following sections provide results of cursory radiation surveys performed at four locations at HPA that were suspected of past operations involving radiation laboratories or radioactive material storage or contamination. Data collection sheets with results of cursory surveys are provided in Appendix B.

5.7.1 Building 351A (Formerly Building 364)

A scan outside and to the north of the building reported that an area at a ground level trench against the building's outside wall was above current USAEC guidelines, where alpha activity was 3500 dpm/100cm^2 using an Eberline AC-3 Alpha Scintillation detector, and the gamma activity was 48,000 CPM using an Eberline SPA-3, 2-inch by 2-inch NaI detector. The concrete lined trench is one of two trenches that lead to a concrete sump approximately 8 feet by 12 feet with an unknown depth. Access to this area was physically hazardous and it was not investigated.

5.7.2 Building 701

No radiation anomalies were found at this site.

5.7.3 Building 816

An alpha, beta, and gamma survey of the building was performed that showed the interior of the building to have gamma activities not significantly different than that of the general area background; the surface alpha and beta activities were not above area background. Current USAEC unrestricted use guidelines of 5000 dpm/100 cm^2 for beta-gamma surface contamination and 20 dpm/100 cm^2 for alpha surface contamination were not exceeded.

5.7.4 Dry Dock 4

No anomalous areas were found during the cursory survey. Scans of ship support structures on the top of wooden blocks and other surfaces in the dry dock showed no anomalous areas. Results of liquid/sludge sampling in the main sump were not conclusive. The percent solids in the liquid/sludge sample matrix was not high enough to obtain low detection limits required for ^{226}Ra analysis. Following completion of this survey, the Navy provided documentation that showed Dry Dock 4 had previously been surveyed and released for unrestricted use.

6.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

6.1 LABORATORY QA/QC RESULTS

The following sections provide QA/QC results for laboratory spikes, blanks, and replicate samples.

6.1.1 Gamma Spectroscopy QA/QC Results

Gamma spectroscopy QA/QC results include the analysis of ^{137}Cs laboratory generated spikes and the replicate counting of soil samples as part of each laboratory work order, specific to each chain of custody. A work order consisted of a maximum of 14 samples. Typically, a work order number was assigned to each shipment of samples from the field when less than 14 samples were submitted in each shipment.

Over the course of this investigation, ^{137}Cs spikes with a known activity were counted 21 times. The range of spike analysis results was 443 to 483 pCi/g. No significant bias was evident, as the mean of 21 analyses of spiked samples was 463 pCi/g while the accepted activity of the spikes was 468 pCi/g, plus or minus 44 pCi/g. The results of the analysis of the ^{137}Cs spike counts are presented in Table 4.

TABLE 4

SUMMARY OF RESULTS FOR ANALYSIS OF CESIUM-137 SPIKE SAMPLE
(Sheet 1 of 2)

Work Order Number	Analytical Result (pCi/g)	Standard Error[1] (pCi/g)
92-01-011 for samples NAI2001, 2002, 2004-2008	483	12
92-01-098 for samples NAI2003, 2009-2024	455	12
92-01-100 for samples NAI2029-2045	472	20
92-01-150 for samples NAI2025-2028	457	10
92-01-151 for samples NAI2046-2051	443	12
92-01-158 for samples NAI2080-2089	450	10
92-01-159 for samples NAI2090-2098	483	12
92-01-160 for samples NAI2055-2058	449	12
92-01-164 for samples NAI2052-2054	475	12
92-01-165 for samples NAI2059-2069, 2071, 2072	453	10
92-01-166 for samples NAI2073-2078	467	10
92-01-200 for samples NAI2100-2104, 2106-2111	464	10
92-01-201 for samples NAI2113, 2115-2118, 2122	463	12
92-02-061 for samples NAI2120-2122, 2124, 2125	465	10
92-02-108 for samples 9206X499, 503, 505-507	449	12
92-02-113 for samples 9206X508-514	474	12

TABLE 4

SUMMARY OF RESULTS FOR ANALYSIS OF CESIUM-137 SPIKE SAMPLE
(Sheet 2 of 2)

Work Order Number	Analytical Result (pCi/g)	Standard Error[1] (pCi/g)
92-02-115 for samples 9206X515, 9206X516	459	10
92-02-117 for samples NAI2127-2131	454	12
92-02-209 for samples NAI2133	466	12
92-02-210 for samples NAI2134-2137	462	12

Note:

[1] Expressed as two times the standard deviation.

The results of replicate counts for gamma spectroscopy on selected soil and water samples are summarized in Table 5. Replicate data are only provided in Table 5 for those analytes that were present in concentrations exceeding the MDA. Non-detectable results were not replicated. A total of 21 replicate counts was made during this investigation.

Replicate counts run on water sample 9206X514 and soil sample NAI2133 appear to have a large discrepancy between replicate results. This is an artifact of the units used to report the water sample results. If the dissolved solids had been in high enough concentration, the sample would have been analyzed as a solid and the activities would have been reported in pCi/g instead of pCi/L. Consequently, the magnitude of the difference between replicates would be similar to that observed for soil samples.

The MDA by gamma spectroscopy of certain samples were distinctly elevated. The problem of high gamma spectroscopy MDA was encountered only in samples where high concentrations of ^{226}Ra were present. A high concentration of ^{226}Ra in a sample interferes with the determination of the other isotopes present. This effect is evident in soil samples NAI2011, NAI2014, NAI2016, NAI2017, NAI2023, NAI2024, NAI2026, NAI2027, NAI2118, and NAI2136.

The appearance of false or highly suspicious peaks also can occur in gamma spectra when high concentrations of ^{226}Ra are present. The appearance of such peaks frequently causes problems for gamma spectroscopy computer software. The overall result is that false positives for certain isotopes may be reported in the samples. The following gamma spectroscopy reported values are highly suspicious: NAI2014 (tin-125 and neodymium-147), NAI2016 (mercury-203 and neodymium-147), NAI2017 (Neodymium-147), and NAI2024 (Hg-203, Tin-125, and Neodymium-147).

The MDA criterion used for gamma spectroscopy is the "lower limit of detection" as defined by National Council on Radiation Protection (NCRP) Report No. 97 (1988). The software used to evaluate the gamma spectroscopy data reported the MDA for an analyte in a sample only when that analyte was not detected. When an analyte was detected in a sample, the activity was reported along with the estimated two standard deviation errors. Table 6 shows the results of QA/QC gamma spectroscopy duplicate soil samples.

6.1.2 Radon Flux QA/QC Results

Radon flux QA/QC measurements included replicate analysis of 10 percent of the canisters analyzed and "blank" analyses on unexposed canisters (5 percent of the canisters analyzed). The

TABLE 5

SUMMARY OF GAMMA SPECTROSCOPY RESULTS FOR REPLICATE COUNTS ON SELECTED SOIL AND WATER SAMPLES

(Sheet 1 of 3)

Sample ID	Activity in pCi/g					
	Am-241	Cs-137	K-40	Ra-226	Ra-228	Th-228
NAI2008	--[1]	--	14.0	1.13	1.44	1.36
NAI2008 Dup	--	--	13.4	0.95	1.24	1.28
NAI2024	2.6	--	--	1523	--	--
NAI2024 Dup	--	--	--	1614	--	--
NAI2028	--	0.035	9.5	1.69	0.51	0.72
NAI2028 Dup	--	--	8.5	1.77	0.34	0.45
NAI2032	--	--	11.7	0.47	0.25	0.27
NAI2032 Dup	--	--	11.1	0.29	0.39	0.55
NAI2045	--	--	9.1	0.41	0.66	0.41
NAI2045 Dup	--	0.055	9.1	0.37	0.45	0.48
NAI2051	--	0.044	14.5	1.26	0.45	0.50
NAI2051 Dup	--	--	15.6	1.20	0.39	0.39
NAI2054	--	--	6.5	0.23	--	0.23
NAI2054 Dup	--	0.08	9.7	0.17	--	0.27
NAI2058	--	0.40	19.2	0.42	0.52	0.51
NAI2058 Dup	--	0.46	18.4	0.46	0.41	0.41

TABLE 5

SUMMARY OF GAMMA SPECTROSCOPY RESULTS FOR REPLICATE COUNTS ON SELECTED SOIL AND WATER SAMPLES
(Sheet 2 of 3)

Sample ID	Activity in pCi/g					
	Am-241	Cs-137	K-40	Ra-226	Ra-228	Th-228
NAI2072	--	--	10.3	0.52	0.33	0.25
NAI2072 Dup	--	--	10.9	0.41	0.86	0.58
NAI2077	--	0.17	13.6	0.46	0.59	0.44
NAI2077 Dup	--	0.14	14.3	0.36	0.46	0.73
NAI2089	--	--	8.9	0.48	0.65	0.40
NAI2089 Dup	--	--	8.6	0.49	0.80	0.57
NAI2098	--	0.376	9.3	0.39	0.37	0.44
NAI2098 Dup	--	0.285	9.6	0.60	0.59	0.50
NAI2111	--	--	--	1.20	2.31	1.92
NAI2111 Dup	--	--	--	1.30	1.89	1.95
NAI2122	--	0.06	8.3	1.30	1.60	1.71
NAI2122 Dup	--	--	8.2	1.30	1.84	1.50
NAI2131	--	0.06	16.1	0.56	0.62	0.56
NAI2131 Dup	--	--	16.5	0.51	0.63	0.80
NAI2133	--	--	110 [2]	--	56[2]	--
NAI2133 Dup	--	--	137 [2]	--	--	--

TABLE 5

SUMMARY OF GAMMA SPECTROSCOPY RESULTS FOR REPLICATE COUNTS ON SELECTED SOIL AND WATER SAMPLES
(Sheet 3 of 3)

Sample ID	Activity in pCi/g					
	Am-241	Cs-137	K-40	Ra-226	Ra-228	Th-228
NAI2137	--	--	19.2	39.7	0.63	0.63
NAI2137 Dup	--	--	19.2	39.9	--	--
9206X514	--	--	54 [2]	--	--	--
9206X514 Dup	--	--	103[2]	--	--	39[2]
9206X516	--	--	14.0 [2]	--	--	--
9206X516 Dup	--	--	13.9 [2]	--	--	--

Note:

[1] Minimum Detectable Activity not exceeded.
[2] Concentration is in pCi/L for these water samples.

TABLE 6

SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL GAMMA SPECTROSCOPY DUPLICATE SOIL SAMPLE RESULTS

Sample ID	Activity in pCi/g					
	Am-241	Cs-137	K-40	Ra-226	Ra-228	Th-228
NAI2008	--[1]	0.21	9.7	0.49	0.49	0.44
NAI2008 Dup	--	0.27	11.0	0.49	0.93	0.42
NAI2089	--	--	9.4	0.52	0.65	0.37
NAI2089 Dup	--	--	8.9	0.48	0.65	0.40
NAI2091	--	0.16	14.8	0.41	0.66	0.41
NAI2091 Dup	--	0.164	12.0	0.37	0.45	0.48
NAI2122	--	--	9.0	1.53	1.54	1.79
NAI2122 Dup	--	0.06	8.3	1.30	1.60	1.71

Note:

[1] Minimum Detectable Activity not exceeded.

minimum detection limit criterion used for radon flux analyses was the "Critical Level" as defined in NCRP Report No. 97 (1988).

The background count rate for the analytical instrument is the sum of the normally detected background radiation and the detected noise that is inherent to the detection system. Radon canister background flux is the gamma activity that exists in an unexposed canister and is calculated as radon flux activity in $pCi \cdot m^{-2} \cdot sec^{-1}$. The background count rate was measured 13 times during the analysis of the radon flux canisters from HPA; the average and standard deviation of the background count rates were 76.94 CPM plus or minus 2.53 CPM.

The average and standard deviation of the count rate of the 32 blanks counted with the HPA samples was 80.43 CPM plus or minus 5.65 CPM. Table 7 summarizes the results of the background count rates for the analytical instrument and the count rates of blank, unexposed radon flux canisters. The difference and standard deviation of the difference between the background and blank count rates on radon flux canisters is 3.5 CPM plus or minus 6.2 CPM, which is insignificant. The standard deviation associated with the average blank count rate is larger than the standard deviation associated with the average background count rate because the blanks were counted for 3 minutes while the backgrounds were counted for 10 minutes.

Table 8 summarizes the results for unexposed radon flux canisters used as trip blanks. None of the trip blanks exceeded the MDA, which ranged from 0.07 to 0.19 $pCi \cdot m^{-2} \cdot sec^{-1}$. Over the course of the SCRS, 11 radon flux canisters were counted as trip blanks.

Over the course of the SCRS, 51 radon flux canisters were counted as replicates. Table 9 shows a summary of radon flux rate results of replicate counts on selected samples. The analytical result is provided in instances where the MDA of 0.15 to 0.30 $pCi \cdot m^{-2} \cdot sec^{-1}$ was exceeded. Of the 51 samples which were counted twice, 12 produced results which exceeded the MDA both times. For these 12 samples, the average absolute difference between the result and the duplicate result was 0.27 $pCi \cdot m^{-2} \cdot sec^{-1}$. The estimated error reported on the radon flux rate results represents two standard deviations of the measured result.

6.1.3 Plutonium Alpha Spectroscopy QA/QC Results

The alpha spectroscopy procedure for isotopic plutonium includes the analysis of a blank, a ^{239}Pu laboratory spike, and replicate samples. The results of the analysis of the ^{239}Pu blank, spike, and replicate analyses are presented in Table 10.

TABLE 7

SUMMARY OF AVAILABLE BLANK AND BACKGROUND COUNT RATE RESULTS FOR RADON FLUX CANISTERS
(Sheet 1 of 2)

Date	Background (CPM)[1]	Blank (CPM)
01/30/92	79.2	--[2]
02/03/92	80.3	--
02/04/92	77.3	--
02/05/92	78.0	--
02/06/92	75.3 81.8	74.6 84.0
02/07/92	75.8	74.6 94.0 75.3 80.6
02/10/92	75.2 75.0	-- --
02/11/92	77.9	81.3 80.6 81.6 81.0 75.0 86.6 74.3 69.0 72.6 79.0 91.6 81.0 75.3 87.0 86.3
02/12/92	76.5	--

TABLE 7

SUMMARY OF AVAILABLE BLANK AND BACKGROUND COUNT RATE RESULTS FOR RADON FLUX CANISTERS
(Sheet 2 of 2)

Date	Background (CPM)	Blank (CPM)
02/14/92	75.9	75.3
		77.6
		82.3
		85.0
		81.6
02/18/92	72.2	75.6
		82.0
		79.3
		84.3
		88.0
		77.6

Note:

[1] CPM = Counts per minute.
[2] Minimum Detectable Activity not exceeded.

TABLE 8

RADON FLUX RATE TRIP BLANK RESULTS

Date	Sample Number	Result $pCi \cdot m^{-2} \cdot sec^{-1}$	MDA[1] $pCi \cdot m^{-2} \cdot sec^{-1}$
01/30/92	1656	0.00	0.13
	0429	0.00	0.13
	0812	0.03	0.14
02/05/92	0625	0.09	0.12
	0346	0.00	0.12
	2037	0.09	0.13
02/06/92	0460	0.00	0.19
02/06/92	3135	0.14	0.16
02/11/92	0298	0.04	0.07
02/12/92	0609	0.11	0.19
02/14/92	0907	0.08	0.13

Note:

[1] MDA = Minimum Detectable Activity.

TABLE 9

SUMMARY OF RADON FLUX RATE RESULTS FOR REPLICATE COUNTS ON SELECTED SAMPLES
(Sheet 1 of 2)

Sample Number	Result ($pCi \cdot m^{-2} \cdot sec^{-1}$)	Duplicate ($pCi \cdot m^{-2} \cdot sec^{-1}$)
0303	74.96	73.47
0429	--[1]	--
0580	--	--
0609	--	--
0625	--	--
0722	0.08	0.13
0812	--	--
0938	--	--
0983	--	--
1053	--	--
1148	--	--
1206	0.10	0.14
1271	--	--
1323	--	--
1368	--	--
1378	47.42	46.61
1402	0.15	0.28
1416	--	--
1420	--	--
1471	--	--
1507	--	--
1565	0.13	0.12
1568	0.26	0.19
1595	0.17	--
1656	--	--
2011	--	--
2023	0.35	--
2030	0.39	0.44
2037	--	--
2047	--	--

TABLE 9

SUMMARY OF RADON FLUX RATE RESULTS FOR REPLICATE COUNTS ON SELECTED SAMPLES
(Sheet 2 of 2)

Sample Number	Result ($pCi \cdot m^{-2} \cdot sec^{-1}$)	Duplicate ($pCi \cdot m^{-2} \cdot sec^{-1}$)
2092	--	0.13
2108	--	--
2125	0.26	0.22
2131	0.09	--
2133	0.13	0.12
2148	--	--
2174	0.22	--
2179	10.96	11.20
2196	--	--
2239	--	--
2289	--	--
3114	--	--
3119	--	--
3147	--	--
3148	0.30	0.35
3151	--	--
3197	--	--
3208	--	--
3300	--	--
3339	--	--
3350	--	--

Note:

[1] Minimum Detectable Activity not exceeded.

TABLE 10

SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL RESULTS FOR ISOTOPIC PLUTONIUM ANALYSES

Work Order Number	Blank Results (pCi/g)		Pu-239 Spike Results[1]
	Pu-238	Pu-239, 240	(pCi/g)
92-01-160 for samples NAI2055-2058	0.002	0.0	2.84
92-03-176 for samples NAI 2011, 2014, 2018, 2022, 2086, 2092, 2096	0.002	0.0	2.41
92-01-164 for samples NAI2052-2054	0.002	0.0	2.84
92-01-165 for samples NAI2059-2069, 2071, 2072	0.033	0.006	2.55
92-01-200 for samples NAI2100-2104, 2106-2111	0.0	0.006	2.31
92-01-20 for samples NAI2113, 2115, 2118, 2122	0.005	0.003	2.31

Sample Number	Results (pCi/g)		Replicate Results (pCi/g)	
	Pu-238	Pu-239, 240	Pu-238	Pu-239, 240
NAI2058	0.103	0.039	-- [2]	0.045
NAI2022	--	--	--	--
NAI2107	0.028	--	--	--
NAI2117	0.051	0.015	0.050	--

Notes:

[1] Spikes had 2.39 pCi/g $\pm$ 0.43 pCi/g of added ^{239}Pu activity.
[2] Minimum Detectable Activity not exceeded.

An amount of ^{239}Pu equivalent to 2.39 pCi/g plus or minus 0.43 pCi/g of sample activity was added to each spiked sample listed in Table 10. For the five spike results available on April 2, 1992, the average ^{239}Pu activity was 2.48 pCi/g plus or minus 0.22 pCi/g. The amount of bias evident in the spike samples was plus 3.8 percent. The MDA ranged from 0.01 to 0.02 pCi/g.

The MDA criterion used for isotopic plutonium analyses by alpha spectroscopy was the "Lower Limit of Detection" as defined by NCRP Report No. 97 (1988). The estimated error reported on the alpha spectroscopy results represents two standard deviations of the measured result.

6.1.4 Gross Alpha and Beta Water Samples

Gross alpha and beta water QA/QC procedures include the analysis of spike samples, blank samples, and duplicate samples. The spike results on selected QA/QC samples are summarized in Table 11 for gross alpha and in Table 12 for gross beta.

The MDA criterion used for gross alpha and gross beta analyses was the "Lower Limit of Detection" as defined by NCRP Report No. 97 (1988). The estimated error reported on the results represents two standard deviations of the measured results. The MDA range for gross alpha analysis was 0.3 to 275 pCi/L and for gross beta analysis was 4.0 to 575 pCi/L. The large range of MDA values observed in the gross alpha and gross beta data analyses are due to the large variations in the amount of dissolved and suspended solids present in the samples. Many of the samples had high concentrations of these parameters. Gross alpha and gross beta screening only yields useful results on samples having rather low concentrations of dissolved and suspended solids.

Over the course of this study, gross alpha spikes and blanks were counted four times. The average absolute difference between the measured alpha activity and the actual alpha activity of the spike was 12.7 percent. None of the gross alpha blanks and duplicate samples had activities that exceeded the MDA criterion.

Similarly, over the course of the SCRS, gross beta spikes and blanks were counted three times. The average absolute difference between the measured gross beta activity and the actual beta activity of the spike was 14.7 percent. None of the gross beta blanks or duplicate samples had activities that exceeded the MDA criterion.

TABLE 11

SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL RESULTS FOR GROSS ALPHA WATER ANALYSES

Work Order Number	Spike Amount (pCi/L)	Spike Result (pCi/L)
92-02-108 for samples 9206X499, 503, 505-507	86	117
92-02-113 for samples 9206X508-514	129	135
92-02-115 for samples 9206X515, 516	2590[1]	2545[1]
92-02-116 for samples NAI 2079, 2099, 2114, 2119, 2123, 2126, 2132	51.8	56.2

Note:

[1] Spike activity in pCi/g.

TABLE 12

SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL RESULTS FOR GROSS BETA WATER ANALYSES

Work Order Number	Spike Amount (pCi/L)	Spike Result (pCi/L)
92-02-108 for samples 9206X499, 503, 505-507	147.2	167.8
92-02-113 for samples 9206X508-514	220.7	252
92-02-115 for samples 9206X515, 516	4414[1]	5122[1]

Note:

[1] Spike activity in pCi/g.

6.2 FIELD QA/QC RESULTS

The field work was completed in accordance with the QA/QC requirements of the work plan and American National Standard ANSI N-323-1978, "Radiation Protection Instrumentation Test and Calibration (1978)". Appendix D provides field operating procedures used during this investigation. Appendix E provides the field equipment lists, response check information, and control charts.

6.2.1 Field QA/QC Relating to Instruments

The TMA/Eberline instruments in use for this survey were all on a periodic calibration program. Only instruments with currently valid calibration certificates were used. The radiation detection equipment was checked for response at the beginning and end of each day or before and after each use. Except for pressurized ionization chambers, the response checks included battery, audio, background, and efficiency checks. For the pressurized ionization chambers, the battery, background, and instrument response to a check source were verified.

Control charts were constructed on which efficiencies were plotted for the 2-inch by 2-inch gamma scintillation detectors. Detectors were only used if the efficiency plotted between the plus and minus three standard deviation bars of the average response recorded on the control chart. Appendix D provides field equipment list, response check information, and instrument control charts.

6.2.2 Field QA/QC Relating to Samples

Twelve trip blanks were included among the 460 radon flux canisters. The results for the trip blanks are provided in Table 8. None of the trip blanks exhibited a result above the MDA. MDAs for the radon flux canisters were generally 0.07 to 0.19 $pCi \cdot m^{-2} \cdot sec^{-1}$. For trip blanks, an east coordinate beginning with the letter X will be found on the radon canister collection form. Sample ID numbers beginning with the letter N were collected by TMA; sample numbers beginning with the numeral 9 were collected by HLA. The radon canister collection form also contains chain of custody information. Two types of field QA/QC samples were provided for soil samples: rinse blanks and duplicate samples. Rinse blanks were analyzed for gross alpha radioactivity. The gross alpha analyses worked well for the rinse blanks due to the low concentration of dissolved solids. The rinse blank gross alpha concentrations were all below the MDA. The MDA for gross alpha activity in the rinse blanks ranged from 0.31 to 0.58 pCi/L.

At certain locations, two samples were collected and submitted for separate isotopic and gamma spectroscopy analysis. Some of the duplicate samples did not meet the plus or minus 20 percent Relative Percent Difference (RPD) criteria for precision. RPDs of 20 to 239 percent were observed for the analyses of ^{40}K and ^{226}Ra. The duplicate analyses for ^{238}Pu and ^{239}Pu had RPDs of 48 to 1000 percent. Many of the duplicate sample results, especially those for $^{238/239}Pu$, had values very close to the MDA. Uncertainty in analytical precision is often observed near the detection limit. Heterogeneity of soil samples may have also contributed to the high RPD values. Details of the sample collection process are handwritten on the field sample collection form. Sample locations, sample numbers, and required analyses are provided on chain of custody documents found in Appendix A.

7.0 RECOMMENDATIONS

The following recommendations are made for further investigation of radioactive materials at HPA based on the results of the SCRS. A detailed work plan scoping the recommended work has been prepared and will be submitted shortly for agency review.

7.1 REMOVE RADIUM CONTAINING MATERIALS IN LANDFILL AREAS

As requested by the Navy, radium containing materials that were identified near or at the soil surface and in shoreline areas of IR-02 investigated during the SCRS will be removed. Discrete gamma emitting, radium-containing materials encountered within 6 inches of the ground surface should be removed to reduce potential human hazard. Following removal of the radium sources, the Navy, through the DOD LLRW program, will dispose of the recovered material.

7.2 INVESTIGATE SUBSURFACE SOIL PROFILE

The depth of contamination of the large radiation anomaly at H.00.00, 16.00.00 in IR-02 needs to be determined. The radon flux at location H.03.09, 16.08.26 was elevated; this location and others within IR-02 should be considered for trenching and soil sampling. At selected locations in the northern area of IR-01, where approximately 15 feet of deposited fill material is present, a sub-surface investigation, including trenching and soil sampling, should also be performed. Additionally, IR-07 and PA-18 should be included in a limited trenching and soil sampling program. Air permeability testing of in-situ soils should also be performed to evaluate the potential effect of compacted soils on radon flux rates.

7.3 INVESTIGATE FORMER NRDL SITES

A plan should be developed to obtain additional information for locations referenced on a map found in Building 810 that shows former Naval Radiological Defense Laboratory (NRDL) sites at HPA. The areas indicated on the map are sites that may have been used for radioactive laboratory operations, material storage, and/or processing. These areas may warrant visual inspection and possible radiation surveys to evaluate surface and general area radioactivity. Other buildings and sites may be included in the survey as more information becomes available.

Some of these sites may have already been released by NRDL for unrestricted use. Search of archived Naval records should be conducted to verify documentation of previous release for unrestricted use. This record search, to be performed mainly by the Navy, should be concluded before Phase II field work begins.

The following is a preliminary list of buildings/sites that may require investigation for radioactivity due to former NRDL activities:

Building 271
Building 351A (Formerly Building 364)
Building 506 Main Naval Radiological Defense Laboratory
Building 509
Building 510 NRDL Annex A
Building 507 NRDL Annex B
Building 520 NRDL Annex D
Building 351 NRDL Annex E
Building 322 NRDL Annex F
Building 313 NRDL Annex G
Building 313A NRDL Annex H
Building 508 NRDL Annex J
Building 224 NRDL Annex K
Building 329
Building 830
Building 831
Regunning Pier and Building 383

Building 351A has two abandoned, concrete-lined utility trenches leading from the rear eastern wall of the structure to a nearby sump. One of the trenches has a small area that is contaminated with alpha and gamma emitters. The extent and nature of the contamination needs to be better defined. The covered sump area and trenches at the rear of Building 351A should be uncovered and examined. A radiation survey should be performed in the sump and appropriate samples taken. Other drainage lines exiting the building from the laboratory area should be investigated. The area behind Building 351A should be secured by locking the access gate.

7.4 PERFORM SINGLE CHANNEL GAMMA ANALYSIS ON SOIL SAMPLES

There are approximately 1,200 archived soil samples in brass liners that require single channel gamma analysis. A single channel analyzer is currently being used to screen new boring samples for elevated gamma activity due to ^{226}Ra. The screening of the archived soil samples previously collected from OU I and OU IV using this method may identify buried zones with elevated gamma activity that may be due to ^{226}Ra.

7.5 SURVEY EXISTING CUTTINGS AND SOILS

The cuttings from previous well installation and other sampling activities are stored in drums in Buildings 414 and 810. The drums are labelled with the boring location that the cuttings were collected from. Prior to the initiation of Phase II field work, the cuttings derived from IR-01, IR-02 and other sites where radioactive contamination is suspected should be screened for elevated gamma activity. Discrete anomalies in the drummed cuttings exhibiting gamma activities above background should be separated and disposed through the DOD LLRW disposal program. If elevated activities are detected, then records should be reviewed to determine the location and depth from where the anomalous cuttings were obtained.

7.6 PERFORM SUBSURFACE GAMMA LOGGING

Additional soil borings are planned at HPA for soil chemical analysis and/or well installation. These soil borings should be investigated by downhole gamma logging. Existing groundwater wells within areas exhibiting surface gamma anomalies should also be gamma logged. Downhole gamma logging will help identify areas where subsurface radioactive contamination is present. Radiochemical analysis should be performed on soil samples collected from anomalous intervals. The northern areas of IR-01 and the large anomaly surrounding grid coordinate H.00.00, 16.00.00 in IR-02 should be investigated in this manner.

7.7 EVALUATE ALTERNATE METHODS FOR RADIOACTIVITY IN WATER

Analysis of water samples with high concentrations of dissolved solids by gamma spectroscopy and gross alpha/beta counting often yield high MDA values. Until a reliable method of preliminary gross alpha/beta screening method can be identified, water samples from HPA should be analyzed by radiochemical de-emanation methods specific for ^{226}Ra and its daughters. Although the presence of dissolved solids does not hinder gamma spectroscopic analysis, the MDAs provided by this method

exceed the MCLs for drinking water. Additionally, groundwater would also be analyzed for the presence of ^{222}Rn.

Wells that had water analyzed using EPA Method 900.0 for gross alpha and beta activity should be resampled and analyzed using alternative analytical methods. These methods include a co-precipitation methodology for quantification of gross alpha, and the use of atomic absorption spectrophotometry for quantification of gross beta emissions by ^{40}K. Radiochemical analysis for the evaluation of specific isotopes such as ^{226}Ra should be considered. Evaluations of these proposed alternative methods will be made in a joint effort with EPA National Atmospheric and Environmental Radiation Laboratory located in Montgomery, Alabama.

7.8 RELOCATE THE SAFE

A combination safe measuring approximately 18-inches by 18-inches by 18-inches in IR-14 was found to have alpha and gamma activity above release guidelines established by the NRC. The safe should be moved to the radioactive materials storage area located in Building 414 and disposed under the DOD LLRW disposal program.

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